

CHEMICAL COMPOSITION VARIABILITY IN EUROPEAN AND ASIATIC SOYBEAN GERMPLASM

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Abstract. In order to identify important sources of germplasm that can be used in the hybridization process to obtain specific soybean varieties, 140 genotypes from Asia and Europe were analyzed. The chemical analyses were performed using spectrophotometry, besides the protein and oil content, one unsaturated fatty acid (stearic) and three saturated fatty acids (oleic, linoleic, linolenic) were determined. In general, a higher protein content has been identified in Asian material. In terms of fatty acid profile, similar results were obtained in both types of germplasm. ES Indicator and Suinong 35 varieties were identified with the highest values for protein content, while for fat content NS-L50101 genotype and Hefeng 54 variety were noted. The strong negative relationship identified between protein and oil highlights that it is difficult to create genotypes that are rich in both parameters. The regression exemplified for the fat and protein content shows that varieties with a protein content of more than 35% and fat higher than 21.75% have not been identified within the European or Asian biological material.

Keywords: soybean, protein, fat, fatty acids, germplasm

INTRODUCTION

Soybean [*Glycine max* (L.) Merr.] is a primary crop cultivated on a large-scale especially for its high protein and oil content. Originated from East Asia (China, Korea, Russia) nearly 5000 years ago (Hymowitz, 2004) and domesticated to increase adaptability to different environments. China has the largest collection of soybean germplasm in the world, but a small percentage is used for breeding, with adverse effects on the genetic diversity of newly created varieties (Qiu et al., 2009).

With an increase of cultivated areas and soybean production in the last 50 years, South America (Brazil, Argentina), northern North America (U.S.A. and Canada), and India are the main soybean producers, countries outside the origin geographic area of the crop (FAOSTAT, 2023).

Soybean is the most important source of vegetable protein known to mankind; it is also one of the cheapest and most available sources of protein, especially in developing countries. The interest for this crop is motivated by the high nutritional value of soybeans (Idrisa et al., 2010).

Liu et al. (2022) stated that the composition of soybean seeds is a complex genetic controlled traits but influenced by environmental conditions (drought, high temperature). Several studies (Cho et al., 2013; Messina et al., 2017; Assefa et al., 2018) specify that the soybean seeds contain between 35-55 % protein and 13-26% oil in dry seed weight basis with a strong negative correlation between these quantitative traits.

Soybean protein contains all the essential amino acids (Friedman and Brandon, 2001) vital for human health, also, five important fatty acids (Bellaloui et al., 2010), two saturated fatty acids (palmitic acid (16:0) and stearic acid (18:0) and three unsaturated fatty acids oleic acid (18:1), linoleic acid (18:2) and linolenic acid (18:3). Regarding the relationship between oil and protein it is reported that could be affected by water and temperature stresses in the seed-fill stage (Lee et al., 2008; Bellaloui, 2011).

Oliva et al., (2006) concluded that soybean genotypes with stable oleic acid and linolenic acid could be used in the breeding programs as a source for new varieties with desirable fatty acids composition. Recently, both oil content and protein content are the main focus due to the increased demand for vegetable oils and food industry applications (Clemente and Cahoon, 2009).

Increasing the protein content is a continuous concern of the European breeding programs (Sudarić et al., 2020). This goal is achieved by an assessment focused on the genetic diversity of the germplasm (Li et al., 2011), and progress can be achieved using conventional breeding (Vratarić and Sudarić, 2008). The influence of environmental conditions on seed composition is outlined by the research of Vollmann et al. (2000) which demonstrates the effect of environmental conditions across growing season and geographic area on seed protein content.

Genetic and phenotypic clustering indicate that geographic-related soybean populations have similar sensitivity to recent climate conditions determining the genetic differences among geographic populations (Liu et al., 2020).

The present study was, therefore, designed to review the variability of the soybean germplasm regarding the chemical composition in order to extend the genetic progress.

MATERIAL AND METHODS

In 2023, at Soybean breeding laboratory from Research and Development Station for Agriculture (RDSA) Turda an experiment with 140 soybean genotypes was conducted.

The biological material studied consisted of 77 genotypes from Europe and 63 from Asia. Each genotype was sown in rows, using 55 germinating grains on m² and a distance of 50 cm between rows. The experiment was sown linearly (Figure 1).



Figure 1. Field view

At maturity, each variant was harvested mechanized, the seeds being analyzed in the laboratory for chemical composition, using spectrophotometry. In this regard, in addition to protein and oil content, one saturated fatty acid (stearic) and three unsaturated fatty acids known for their benefits on human health (oleic, linoleic, linolenic) were analyzed.

The data obtained were statistically processed using frequency calculation, descriptive statistics, correlations and regression analysis. Statistical analysis was performed using Microsoft Excel and Past4.

RESULTS AND DISCUSSIONS

Due to the importance in the human diet and the increasing demand for vegetable proteins (EC, 2021), the creation of biological material tolerant to less favorable environmental conditions have made more and more areas of Europe suitable for soybean cultivation.

The variability of soybean seed content in protein, oil and fatty acids may be influenced by genotype, environment, management practices and their interactions (Bellaloui et al., 2011).

If there is genetic variability, progress in creating genotypes with a high protein and oil content and an improved fatty acid profile can be achieved by the classical breeding method, i.e. hybridization followed by repeated individual selection in hybrid populations. Starting from this consideration, characterizing the material by performing chemical and biochemical analyzes is a first step in this process.

From the analysis of protein content in the 140 soybean genotypes, depending on origin, the superiority of Asian material is noted, which, on average, had a protein content of 35.59%, 1.7% higher than the average of European cultivars (Figure 2). While only 16 of the 77 European genotypes had a protein content higher than 36%, more than half of Asian genotypes (35) achieved protein values higher than 36.6%. For the variability coefficient, the values of 5.17% and 4.35% respectively were obtained. The magnitude of variation of this parameter was 7.97% for cultivars from Europe and 7.26% for Asian soybean genotypes. The experiment's maximum of 38.73% was identified in germplasm from China.

Soybean genotypes with a higher protein content have been created in combination with a comparable yield, improving the existing biological material, which is extremely valuable for the production of protein-rich soybean meal (Gillenwater et al., 2023). The literature provides multiple information in which biotic and abiotic factors that can influence protein content are described, the genetic factor is the most significant, followed by the climatic factor (in years with excess humidity the protein content is higher than in dry seasons), as stated by Wenda-Piesik et al. (2022).

The protein percentage is higher for Asian varieties due to advance of soybean breeding and pedigree programs that have focused particularly on protein content (Patil et al., 2017) and less on production components.

In terms of fat content (Figure 3), the negative relationship between protein and oil is highlighted by the higher values of this parameter identified for material originating in Europe, with an average of 21% and a maximum content exceeding 24%. Of the 140 genotypes studied, 51 European varieties and 44 Asian soybean varieties exceeded 20.35%. The experiment maximum of 24.23% was identified within the European germplasm. Even though the range was about 6% in both germplasm groups studied, the values obtained for the variability coefficients were relatively small (5.48%, 4.74%). The existence of a large variability in terms of oil content offers greater chances of success in creating varieties for the processing industry. The results obtained by

Urdă et al. (2021) indicate a high heritability for the quality indices analyzed, with special importance in the breeding process. In a study conducted by Zhang et al. (2008), narrowing of the genetic base of Chinese germplasm was observed by artificial selection. Thus, within wild soybeans, there was a greater variability in terms of fat content, but better values for this parameter, on average by 6% higher, were observed in the cultivated varieties.

Protein and fat content are one of the major soybean seeds quality features with importance in human health (Islam et al., 2023). Some studies (Guo et al., 2022) have shown that the percentage of protein in soybeans is most often correlates negatively with oil content, as their synthesis compete for limited carbon and energy supply.

The protein content of soybeans also negatively correlates with other traits, such as yield, the height of the plant, number of knots on the main stem, timing of flowering, and reaching maturity (Dhungana et al., 2017).

There is a negative correlation between the main quality components of soybeans (protein and oil), with data reported by Clemente and Cahoon (2009) showing that for every 2% increase in protein content, the oil content is reduced by about 1%.

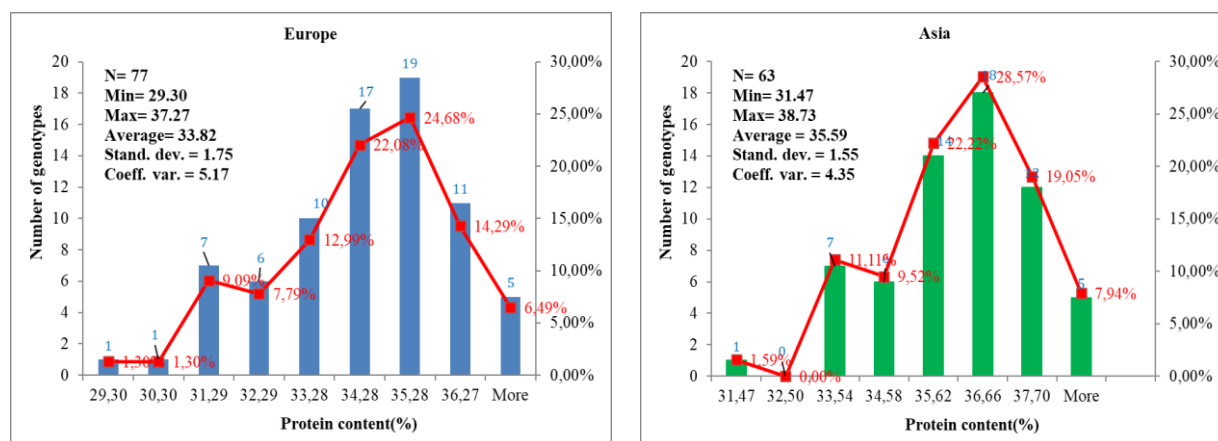


Figure 2. Protein content variability in 140 soybean genotypes

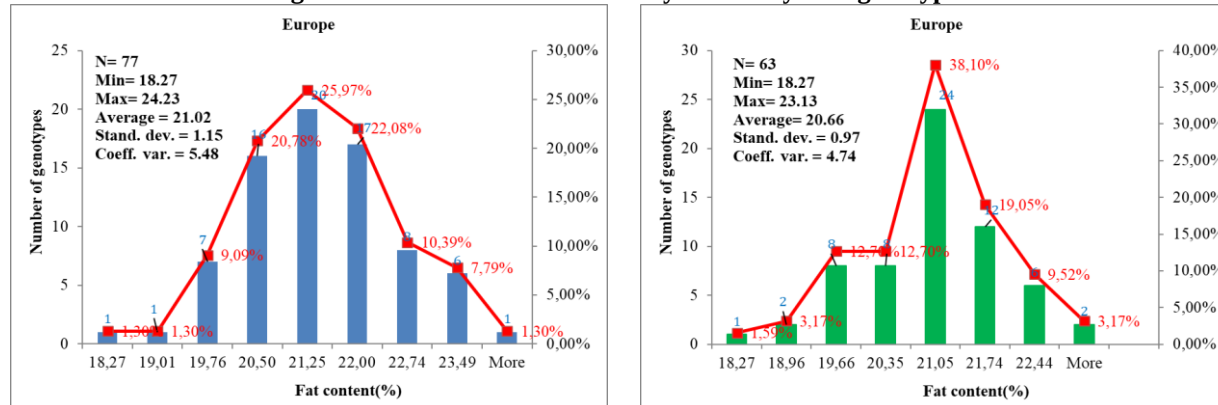


Figure 3. Fat content variability in 140 soybean genotypes

The fatty acid profile of soybean oil provides important information about its stability and quality, in general, according to some authors (Fehr, 2007), the oil content of soybeans consists of approx. 13% palmitic acid, 4% stearic acid, 20% oleic acid, 55% linoleic acid and 8% linolenic acid. Stearic acid is a saturated acid that enhances the stability of soybean oil. The values obtained for both groups of germplasm are similar, averaging about 4.7% and a variability coefficient of 6%. While 18 of the Asian genotypes had a stearic acid content greater than 4.9%, the majority (24) of the 77 European genotypes, had a stearic acid content between 4.43-4.62% (Figure 4).

In terms of oleic acid, small variation ($CV < 3\%$) was identified in the experiment. Higher values for this parameter were observed in the Asian germplasm, 42 genotypes obtained more than 25.46% content of oleic acid (Figure 5).

Studies by Combs and Bilyeu (2019) have shown that oleic acid in concentrations higher than 70% as well as α -linolenic acid less than 3% improve oil stability and provide health benefits.

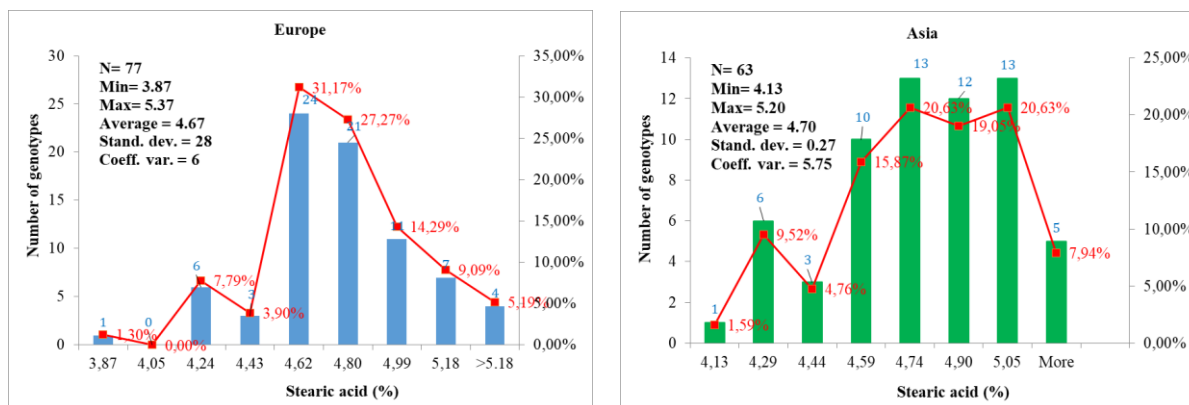


Figure 4. Stearic acid variability in 140 soybean genotypes

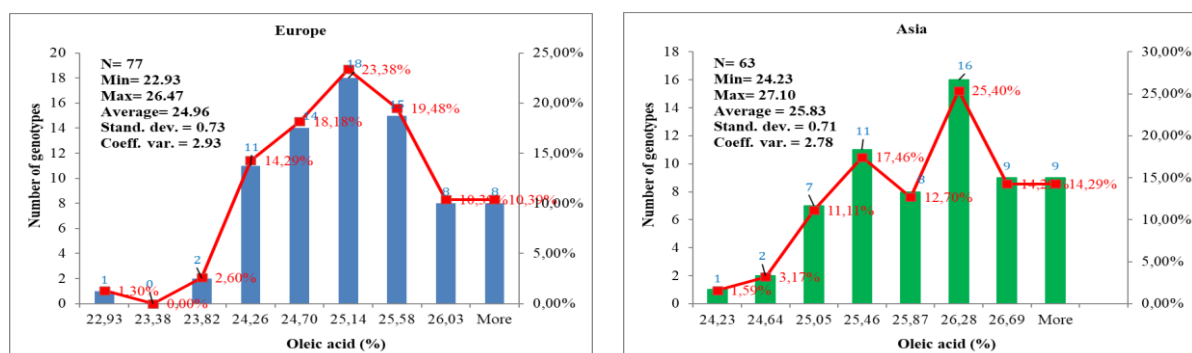


Figure 5. Oleic acid content variability in 140 soybean genotypes

Grouping genotypes according to oleic acid content reveals that both Asian and European genotypes are characterized by close values for these important oil quality indicators (Figure 6). Higher than 4% range for obtained values in both types of germplasm were observed, the maximum of 56.2% being reached within the Asian group.

The study by Abdelghany et al. (2020) showed that biological material of Asian origin has a higher content of acids (palmitic, stearic, linoleic and linolenic) than biological material from the USA and that Asian germplasm could be used as good genitors for the creation of soybean varieties with high saturated oils.

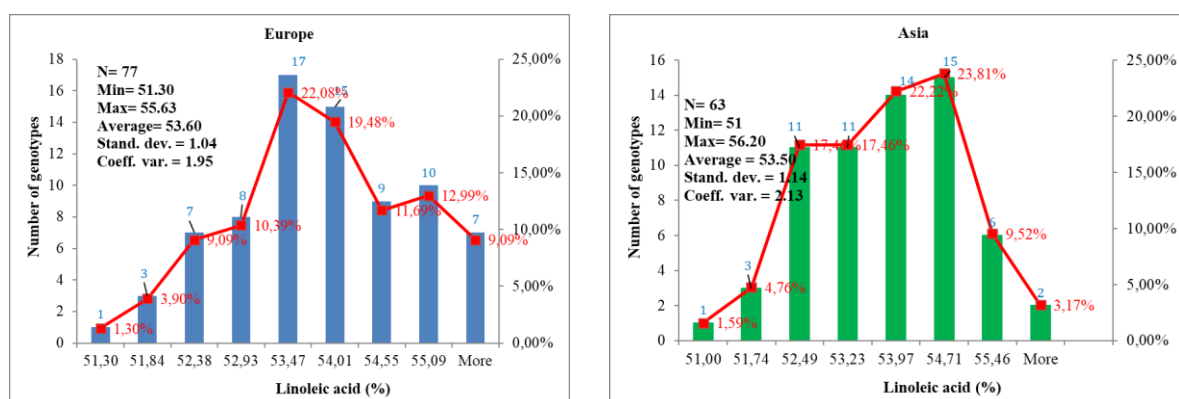


Figure 6. Linoleic acid content variability in 140 soybean genotypes

For linolenic acid content (Figure 7), high variability was identified (coeff. var. > 19%). The extreme values for this quality parameter were identified in the Asian germplasm, 34 genotypes had superior than 5.7% of linolenic acid. In terms of European genotypes, higher than 7.12% of this unsaturated acid was obtained in 26 varieties. Of interest, are the two genotypes that registered values of less than 3% for linolenic acid content. A variability of linolenic acid content depending on genotype was also identified in a study conducted in order to evaluate the influence of crop rotation and inoculant treatment on soybean quality (Balaş et al., 2021), with the Cristina TD variety with values lower than 2% for this parameter.

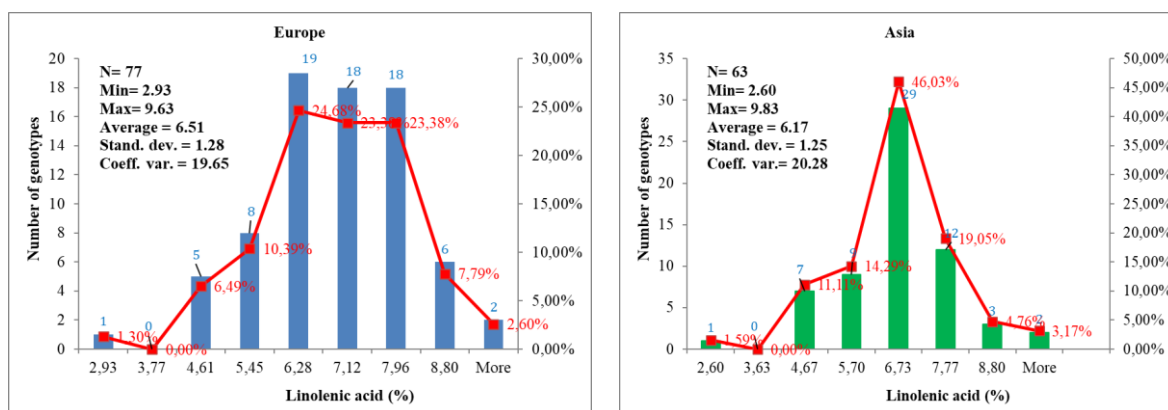


Figure 7. Linolenic acid content variability in 140 soybean genotypes

Although there is currently significant area in Europe on which different soybean varieties are grown, an important reason for the expansion of soybean cultivation in the central and northern areas of the continent is the high demand for soy protein, which would require the use of 9-12% of the arable land on which soybeans are planted (Guilpart et al., 2020).

The existence of negative correlations between the analyzed quality parameters makes it difficult to improve them simultaneously. However, it would seem that, in germplasm from Europe, positive relationships were identified between stearic acid content and oleic acid content ($r=0.51$), respectively protein ($r=0.14$), oleic acid and fat ($r=0.33$) and between linolenic acid and fats ($r=0.41$).

The strong negative relationship identified between protein and oil ($r=-0.84$) highlights that it is difficult to create genotypes that are rich in both parameters. The regression exemplified for the fat and protein content (Figure 8) shows that varieties with a protein content of more than 35% and fat higher than 21.75% have not been identified within the European material. However, for the improvement in terms of protein content, 6 genotypes were noted, the maximum of the experiment being reached by the ES Indicator genotype. Regarding fat content, 14 genotypes that had high values for this parameter can be used as genitors, the variety with the highest oil content being cultivar NS-L50101.

For the Asian germplasm, similar relationship between quality parameters were observed (Figure 9), with higher value for correlation coefficient calculated between stearic and protein content ($r=0.40$). Regarding the relationship between protein and fat content, strong negative link was observed ($r=-0.76$).

The inverse correlation between protein content and oil content is well known and is thought to be caused in part by the action of pleiotropic genes and competing metabolic pathways, which control the expression of each trait (Guo et al., 2022).

As in the case of European material, no genotypes that have at the same time a protein content higher than 35% and oil above 21.75% have been identified. However, the superiority of Asian material in terms of protein is obvious, most varieties having a content of more than 35%, the maximum being reached in the Suinong 35 variety.

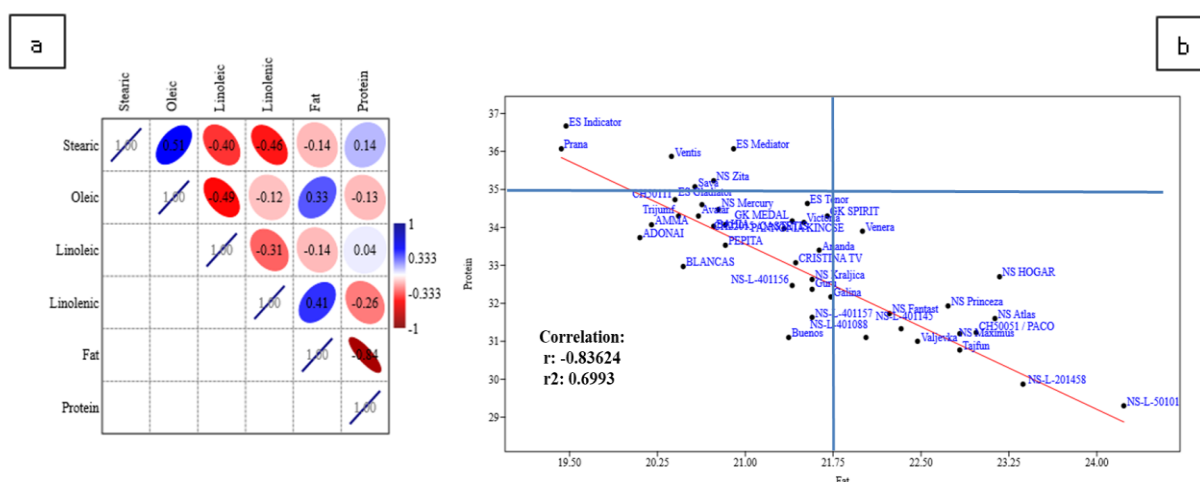


Figure 8. Correlation between quality parameters obtained in European germplasm (a-Pearson coefficient between quality parameters; b- regression analysis between fat and protein content)

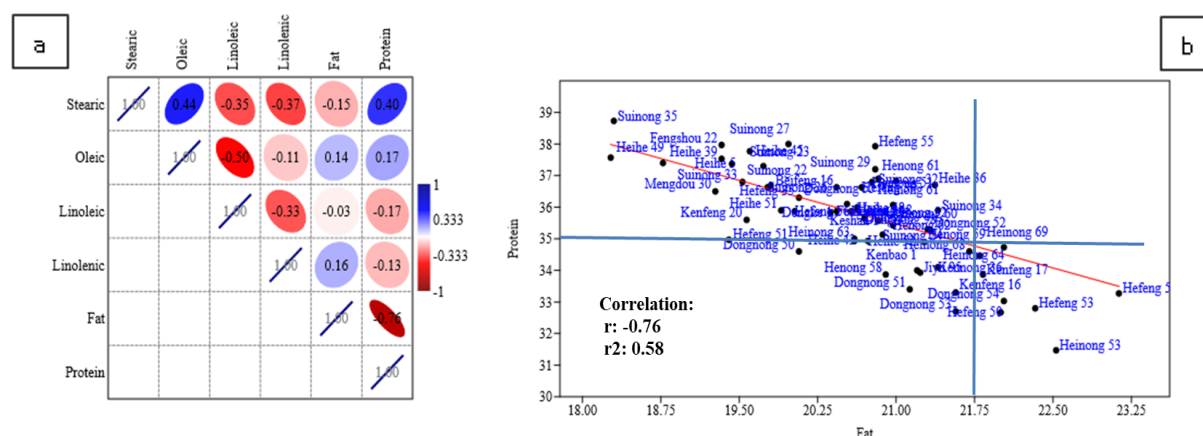


Figure 9. Correlation between quality parameters obtained in Asian germplasm (a-Pearson coefficient between quality parameters; b- regression analysis between fat and protein content)

CONCLUSIONS

The high variability identified within the analyzed biological material revealed valuable genotypes that can be further used in crossbreeding, in order to obtain soybean varieties that ensure not only high yields but also quality.

Within the European germplasm, the ES Indicator variety can be used as a genitor to increase protein content, and the NS-L50101 genotype is recommended for increasing oil content.

Regarding the germplasm of Asian origin, Suinong 35 variety for protein content and Hefeng 54 variety for fat were noted. In general, a higher protein content has been identified in Asian material. In terms of fatty acid profile, similar results were obtained in both types of germplasm.

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