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Analysis of nutritional value for soya-bean genotypes grown in Lesotho

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Abstract

Soya-bean crop is introduced in Lesotho to widen the spectrum of legumes that have a potential to provide highly nutritious food in particular protein, oil and carbohydrates. Since its introduction into the country a decade ago, determination of nutritional value has not been performed, hence the study is conducted. The objective of study was to distinguish soya-bean genotypes on the basis of nutritive value. The experiment was laid out using Randomized Complete Block Design with 27 treatments (genotypes) and three replications. Compound fertilizer of 2:3:2 (22) was broadcast over main experimental plot at the rate of 250kg ha^{-1}. The dimensions of main experimental plot were 135m long and 10m wide with each sub-plot being 4m and 3.6. Inter-row spacing and intra-row spacing were 0.9m and 0.20m, respectively. The samples of seeds from each plot were taken to the laboratory to analyze protein content, ash, ca, mg and acid detergent fibre. The results revealed significant differences (P>0.05) among 28 soya-bean genotypes for protein content, acid detergent fiber, calcium, magnesium and ash content. The soya-bean cultivars with the highest amount of protein were P48T48R, PAN 1663 and PAN 155R. High ADF content was expressed by PAN 1521R. LS 6868 exhibited the highest value of 0.788mg Calcium. The cultivar with highest magnesium was NA 5509 with 1.306mg. PAN 1663, LCD 5.9, DM5302 RS and NS 6448R revealed higher nutritional values than other genotypes.

Index Terms *– Genotypes, Glycine max L. Merill**,** Lesotho, nutritive value, proximate analysis.*

INTRODUCTION

Soya-bean (*Glycine max L. Merrill*.) is a leguminous crop originating from Eastern Asia, China. It then spread to other parts of China, South and North America where it gained popularity (Sedivy, 2017). It was initially used for feeding animals in vegetative stage, but later whole grain was fed to animals. It is currently a major ingredient in livestock feedstuff such as pigs, chickens, cattle, sheep, horses and fish (Rada *et al*. 2017). Soya-bean started to be used for human consumption later where it was processed into many products which include amongst others; soya flour, soya protein, tofu, soya milk, soya sauce, soya bean oil, coffee and nuts (Delele, 2021).

Soya-bean is highly nutritious containing 36-56% protein, 35% carbohydrates, 18% fat, 17% dietary fibre and 5% minerals and many vitamins (Ali *et al.*2020). It is a cheap source of protein affordable by many households. The nutritional profile of soya-bean is similar to that of animal proteins except that it is deficient of Sulphur containing essential amino-acids, thus methionine and cysteine (Ali *et al*., 2020). According to international standards of protein quality determination, soya-bean protein has a biological value of 74, whole grain soya-bean 96, soya-bean milk 91 and eggs 97 (Food and Agriculture Organization, 2020).

Besides having high protein, soya-bean has a high oil content compared to other crops, hence called an oil crop. An oil extracted from soya-grain is used for animal feed, industrial purposes and human consumption. It constitutes 16% saturated fatty acids, 23% mono-unsaturated fatty acids and 58% poly-unsaturated fatty acids (Demarco and Gibon, 2020). Digestibility of soya-bean varies greatly depending on the processes it has undergone during preparation such fermentation, boiling, frying, roasting, baking, heat treatment or enzymatic hydrolysis. On an average, digestibility of soya-bean is 65% when steamed, 93% tofu, soya-milk 93%, and 97% soy protein isolate (Delele, 2021).

Carbohydrates found in soya-beans are of two groups, non-structural and structural. Non-structural carbohydrates include lower molecular weight sugars, oligosaccharides and storage

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polysaccharides. While the second group is constituted by the structural polysaccharides and dietary fibre. Dietary fibre is a heterogenous mixture of cell wall polysaccharides, non-cellulose poly-saccharides, and nonstructural poly-saccharides such as lignin and phenolic components. Components of dietary fiber have their own unique chemical, physical and nutritional properties (Araujo-Chapa *et al*, 2023).

Nutritional value of soya-bean constituted by protein, carbohydrates, fibre, oil, minerals and vitamins, varies greatly depending on the soya-bean genotypes and environment in which they are grown. These differentials are attributed to genotypic constitution in part which is dissimilar to a certain extent. The proportion of nutrients among soya-bean genotypes differ necessitating quantification by the use of proximate analysis recognized internationally. It is therefore of utmost importance to identify the genotypes with high proportions of nutrients. The study was undertaken with the objective of distinguishing genotypes on the basis of nutritional value.

MATERIAL AND METHODS

Study area

The laboratory experiment was conducted at The National University of Lesotho, Faculty of Agriculture, in the Department of Crop Science. The coordinates of The University are 29^o 26’ 48 South latitude and 27^o 42’ 29 East longitudes with the altitude of 1610m above sea level.

Source of germplasm

Twenty-seven (27) soya-bean genotypes were obtained from the Department of Agricultural Research in the Ministry of Agriculture and Food Security, Maseru, Lesotho. The genotypes were evaluated across all four (4) agro-ecological zones of Lesotho, namely; Lowland, Foothills, Mountains and Orange River Valley. The zones are distinct in characteristics based on altitude, climate, edaphic and vegetation. Their agricultural potentials differ greatly.

Experimental Design

The dimensions of main plot were 135m long and 10m wide with each sub-plot being 4m and 3.6m. Inter-row spacing and intra-row spacing were 0.9m and 0.20m, respectively. Randomized Complete Block Design was employed to lay-out 27 treatments (genotypes) with three replications. Compound fertilizer of 2:3:2 (22) was broadcast over main plot at the rate of 250kg ha^{-1}. The 200 seeds from each plot were taken to the laboratory to analyze protein content, ash, calcium, magnesium, acid detergent fibre and neutral detergent fibre.

Laboratory procedure

Crude protein

The total samples of about eighty-four (84) were used in milling. Only 0.5g from each sample was taken to the digesting machine when running protein test. The Kjeldahl method developed in 1883 by a brewer called Johann Kjeldahl was adopted in protein test. It was digested with a strong acid (selenium power and hydrogen peroxide 30%) so that it releases nitrogen which can be determined by titration using hydrochloric acid technique. The amount titrated was worked out using the formula (Na x Va x 1.4 ÷ weight of sample), after which this amount was converted to protein by multiplying the figure with a constant of 6.25.

Where Na= Normality
Va= Volume of titration

Acid Detergent fibre

One gram (1g) of air-dried sample from each cultivar was poured in the beaker. 100 ml of acid detergent solution (20g of cetyl trimethyl ammonium bromide in sulphuric acid to the volume of 1L) was added in the sample, after which 2 ml of deca-hydro naphthalene was again added. Then the mixture was heated to boil for an hour. Thereafter, the mixture was filtered to get supernatant. Sintered glass crucible was weighed (w1). The supernatant was kept in the crucible. In the crucible, samples were rinsed with hot water and acetone. Then the crucible was placed in a hot air-dried oven for eight hours and weighed afterwards (W2), then the difference between W2 and W1 is the amount of fiber present.

Ash content

The milled sample of 2g were placed in pre-weighed crucible (W1), crucibles were placed in a muffle furnace and heat to 600ºC for 2 hours. At that temperature all organic matter was burnt leaving behind minerals. After the crucible containing burnt sample cooled, they were weighed (w2), the difference between W1 and W2 was ash content of the sample.

Calcium content and Magnesium content

The samples remaining after determining crude protein was used to determine Calcium and Magnesium. Atomic Absorption Spectroscopy (AAS) was used to measure the concentrations of Ca and Mg in each sample. It is a process involving the absorption by free atoms of an element of light at a wavelength specific to that element. The liquid samples were used to be aspirated, aerolized and mixed with combustible gases such as acetylene and air or acetylene and nitrous oxide, then the amounts of calcium and magnesium were shown respectfully.

Data collection

The readings from Atomic Absorption Spectrometer were taken as concentration of Calcium and Magnesium. Crude protein content, acid detergent fiber, neutral detergent fibre and ash constituted data.

Data analysis

The data generated on the above-mentioned parameters were subjected to analysis of variance using GenStat software package version 12. To establish the difference among the cultivars for the parameters measured, least significant difference was used to compare the means.

RESULTS

There were significant differences (P>0.05) among 28 genotypes for protein content, acid detergent fiber, calcium, magnesium and ash (Table 1). The soyabean cultivars with the highest amount of protein were P48T48R, PAN 1663 and PAN 155R with 37.81%, 33.431% and 32.488, respectively. Whereas three cultivars with lowest protein content were NS

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5909R with 21.206, followed by PAN 1521R and LS6860R with 22.2% and then SSS 5449 tuc with 22.78%. High ADF content was expressed by PAN 1521R with 0.967, followed by PAN 1663 with 0.787mg. The lowest cultivar in ADF was NA 5509R with 0.127. Only one cultivar had a higher amount, which was PAN 1521R with 1.28mg and many of cultivars had low quantity. Regarding Calcium, LS 6868 exhibited the highest value of 0.788mg, followed by PAN 1663 with 0.663mg and DM 5351 RST with 0.641mg. The lowest values were experienced with LS6888 revealing 0.146, followed by LS 6I64 with 0.165 and PAN 172 with 0.175 mg. The cultivars with highest magnesium were NA 5509 with 1.306mg, followed by DM 5302 with 1.259mg and LS 6868 with 1.23 mg. The lowest magnesium contents were found in LS 6851, LDC 5.3 and PAN 1644R with values of 0.416mg, 0.431mg and 0.44mg, respectively. Twenty-seven cultivars had the average of 0.1mg (Table 2). PAN 1663, LCD 5.9, DM5302 RS and NS 6448R revealed higher nutritional values than other genotypes.

Table 1 Analysis of variance for nutrients parameters

Source of variation	df	Mean square				
		Protein	Acid Detergent Fibre	Calcium	Magnesium	Ash
Replication	2	1.144	0.001	0.082	0.103	0.023
Genotypes	27	1.220*	0.101*	0.104*	0.280*	0.213*
Error	54	0.170	0.001	0.044	0.017	0.028
CV		7.2	17.5	13.6	7.7	13.6
LSD		0.899	0.364	0.459	0.282	0.459

Significant levels: P>0.01*highly significant, P>0.05**Significant, df = degrees of freedom

Table 2 Means of soya-bean genotypes for different nutrients

Genotypes	Protein %	Calcium (g)	Magnesium(g)	ADF mg	ASH (g)
Dm 5953 RSF	24.131b	0.232b	0.478c	0.173e	0.067e
PAN 1644R	23.537b	**0.386a**	0.44c	0.173e	0.083e
Ls 6851 R	29,138b	0.179b	0.416c	0.167e	0.077e
LDC 5.3	26.656b	**0.417a**	0.431c	0.17e	0.07e
Dm 5901 RSF	26.425b	**0.39a**	0.653c	0.2d	0.087e
NA 5509 R	27.048b	**0.321a**	**1.306a**	0.127e	0.083e
NS 5909 R	21.206c	0.231b	0.623b	0.143e	0.087e
LDC 5.9	**31.094a**	**0.637a**	**1.146a**	0.207d	0.077e
PAN 1575 (JSS 2713)	24.858c	**0.612a**	**1.23a**	0.237c	0.077e
LS 6868	25.363c	**0.778a**	**1.23a**	0.25e	0.08e
PAN 1663	**33.431a**	**0.663a**	**1.135a**	0.787b	0.087e
DM 6.81RR	25.306b	**0.459a**	0.552b	0.243c	0.077e
P64T39R	**30.219a**	0.24b	0.356d	0.16e	0.09e
P48T48R	**37.381a**	**0.507a**	0.682c	0.23c	0.093e
DM 5302 RSF	**31.138a**	**0.566a**	**1.259a**	0.17e	0.113b
NS 6448 R	**31.319a**	**0.635a**	**1.149a**	0.223d	0.067e
LS 6888	**32.888a**	0.146b	0.831b	0.163e	0.103d
LS 6164	29.894b	0.165b	0.614c	0.17e	0.087e
P61T38R	28.756b	0.292b	0.803b	0.187d	0.087e
PAN 1555R	**32.488a**	0.172b	0.425c	0.283c	0.087e
SSS 5052(TUC)	26.3b	0.242b	0.601c	0.24c	0.083e
PAN 1521R	22.2c	**0.458a**	0.691c	**0.967a**	**1.28a**
DM 5351 RSF	23.894b	**0.641a**	0.998b	0.173e	0.103d
SSS 5449 (tuc)	22.78b	**0.428a**	**1.012a**	0.177d	0.283c
Ls 6860R	22.781b	**0.514a**	0.455c	0.187d	0.09e
SSS 6560(TUC)	**30.569a**	0.2634b	0.704b	0.237c	0.073e
LS 6161 R	25.306b	**0.438a**	0.863b	0.187d	0.103d
DM 6968R	23.581b	**0.438a**	0.987b	0.28c	0.87e

Table 3 below showed the magnitude of genotypes, environment and phenotype variance on protein, acid detergent fibre, Calcium, Magnesium and Ash content. It was revealed that genotypic variance was high on all the parameters measured than environment. Calcium and Ash content were highly variable among the soya-bean cultivars. The least variable compared to other nutrients is protein content. The variation of the environment contributing to protein, acid detergent fibre, Calcium, Magnesium and ash was infinitesimal and consistent across them as depicted in Table 3. Phenotypic values exhibited wider variations in Calcium and Ash content and very narrow on protein content.

Table 3 Components of variance

Components	Protein	Acid Detergent Fibre	Calcium	Magnesium	Ash
Genotypic (δ^2_g)	0.917	100	8.923	2.553	8.0435
Environmental(δ^2_e)	0.170	0.001	0.044	0.017	0.028
Phenotypic(δ^2_p)	1.087	100.001	8.967	2.570	8.0715

DISCUSSION

Among 28 cultivars, nine of them had high amount of protein with the average of 34.54% and this was due to their genetic constitution which enabled them to efficiently absorb more nitrogen from both soil and atmosphere, after which it was assimilated into plant systems where it was highly converted into protein. On the other hand, three cultivars had low protein content with average of 12.041%. Conversely, low proteins in some of these cultivars were as a result of low absorption by the plant roots and nitrogen use inefficiencies by the plant system. The cultivars of soya-beans differed greatly in their ability to absorb and utilize nitrogen, hence there was a wide spectrum of protein content in the 28 cultivars. This was supported by Ishii *et al*., 2011 who observed wide variation in his study of soyabeans. The higher the capability of the plant to absorb nitrogen, the higher the quantity of protein is synthesized. Cultivars with combination of genes conferring high protein content are most preferred where protein is a concern. Biel *et al*., (2018) in his study also found that most cultivars had high protein content while few had low protein content. In a similar study conducted by Mirwais *et al*. (2016) using 108 cultivars of soya-bean, the findings revealed a wide variation in protein content which he attributed it to variation in genetic constitution of the germplasm used.

Out of 28 soya-bean cultivars, Ca content was high in 18 with the average of 0.516mg and 10 had low amount with the average of 0.216mg. This was also a resultant of variation of gene combinations which determined the absorption rate of Ca in the soil and its accumulation in the plant. The findings were consistent with those of Purwantoro *et al*. (2017) who compared calcium content of 48 soya-bean cultivars and obtained a wide spectrum of calcium content among cultivars with some having high content, while others exhibited a very low content.

Eight cultivars had high amount of Magnesium with the average of 1.183mg, while nine had low content with average of 0.586mg. Similarly, genetic make-up of the cultivars differed greatly conferring low, average and high magnesium content. This variation can be exploited particularly in soya-bean cultivars with high Calcium content by incorporating in the breeding programme. Haliru *et al*. (2017) in his research discovered that magnesium was very low in soya-bean cultivars and recommended a breeding programme that could aim at increasing the level of Ca in soya-bean to that of daily human intake as prescribed by Food and Agricultural Organization. Mirwais *et al*. (2016) found that in twelve soybean cultivars, the seed magnesium content to range from 1.67 to 2.23 mg, which was consistent with the results of the present study that Mg differs with cultivars.

Only one cultivar had high amount of ADF being PAN 1521R with 0.967mg and 12 cultivars had low quantity with the average of 0.170mg. The genetic combination conferring fibre syntheses were unfavourable to manufacture and accumulate a high amount in the plant. The results support the findings of Biel et al. (2018), who identified very few cultivars having high fibre content. Purwantoro et al., (2017) in the study of soybean where several nutrients tested, found that acid detergent level differed with cultivars. He further stated that the level was related to the maturity stages of crop with increased cell-wall components, especially cellulose, hemicelluloses and lignin. Lastly on ash, only one cultivar had high amount which is PAN 1521R with 1.28mg and many of cultivars had low quantity, 24 cultivars with the average of 0.1mg. According to Haliru et al. (2017) on their study of assessment of nutritional characteristics of products developed using soybean, found that the content of ash differed in cultivars and the range was (2.90 ± 0.04%) of many cultivars.

CONCLUSION

The cultivars differ greatly in their genetic make-up and are being affected by environment. Among soya-bean cultivars, there were great genetic variability which led to variation in parameters measured. Nonetheless, some cultivars are close to the other forming groups of isogenic lines. They differ in one or more parameters. Those that are close to each other in most parameters suggest that they may share common parentage or progenitors. Other cultivars are complete outliers suggesting no similarity or relationship. This dissimilarity assists in the adoption of cultivars in different localities. Some are widely adapted while others are site-specific. Preliminary selection can be undertaken as which cultivars can be grown between the two localities and give higher nutritive value and which ones are stable across the two localities in terms of characteristics measured.

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