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Research Article

Evaluation of physiological and biochemical traits in some improved soybean lines in Makurdi, Nigeria

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Abstract

Twelve genotypes of soybean were subjected to physiological and seed biochemical studies at Joseph Sarwuan Tarka University, Makurdi. These seeds were collected from NCRI Badegi; Niger State- Nigeria. Ten of these genotypes S1075-6-93, S1179-6-58, S1239-6-135, S1240-6-288, S1252-6-277, S1252-6-156, S1268-6-15, S1273-6-65, S1365-6L-20 and SC SENTINEL was newly introduced to Makurdi while SC SIGNA and SLO1 have been released. Seed samples were collected and subjected to seed quality tests at the Department of Plant Breeding and Seed Science Laboratory of the University. Data were collected on germination count which was expressed as germination percentage, germination rate and germination rate index. These seeds were also subjected to proximate analysis and percentage protein, fat, ash, moisture content and crude fibre were determined. The result showed that significant differences existed for germination rate index (GRI) and germination index (GI) while other seedling traits were not different statistically from each other. Protein was highest in three gnotypes (S1075-6-93, S1239-6-135 and S1252-6-156) with 40.25%, respectively and significantly different from others and the checks. SC SENTINEL had the least protein content (37.19) and highest oil content (20.82). Meanwhile, genotype S1239-6-135 had the least oil content (18.83). Compositionally, an inverse relationship existed between protein oil in genotypes studied. Biochemical composition has more effect on seed quality of these soybean genotypes than physiological traits. Genotypes (S1075-6-93, S1239-6-135 and S1252-6-156) had higher protein content than the checks. Also, Sc SENTINEL, S1365-6L-20, S1273-6-65, S1268-6-15 and S1240-6-288 had higher oil content than the checks. Soybean oil producers could use SC SENTINEL for their oil productions and (S1075-6-93, S1239-6-135 and S1252-6-156) could be used for protein-based products.

Keywords: *Proximate, Seedling Vigour, Physiological, Biochemical, traits*

Introduction

Soybean (*Glycine max* (L.) Merrill) is a key player for global food security (Dilawari *et al.*, 2022). Soybean is considered a triple beneficiary crop, for the fact that it contains 20 % oil and 38-42 % high quality proteins, and equally fixes atmospheric nitrogen in the soil at the level of 150-200 kg per hectare per season. Globally, soybean production has been increasing due to the high demand of soy products for food, feed and the developing market for biodiesel to replace the depleting fossil fuel resources.

Soybean is a highly nutritious food item and it is known for its wide range of agricultural, food, and industrial applications as well as health benefits (Cabanos *et al*., 2021). Seed storage compounds are of crucial importance for human diet, feed and

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industrial uses, as they are mainly composed of starch, proteins and oil (Jasinski *et al.*, 2018). Soybean on the average has 40% protein and 20% oil respectively and is thus considered as a highly nutritional value crop.

Soybean seed quality is often determined by its constituents which are important to sustain overall nutritional aspects (Wijewardana *et al*., 2019). Soybean is grown mainly for its protein and oil component. Protein and oil are the two principal seed constituents that make soybean (*Glycine max*) an important crop (Ailin *et al.*, 2022). The actual composition of the whole soybean and its structural parts depends on many factors, including varieties, growing season, geographic location, and environmental stress. Environmental factors, which vary spatially and temporally during the growing season and among years, play a major role in controlling soybean seed yield, quality, and its chemical composition (Wijewardena *et al*., 2019).

Its yield has been associated with high instability at different environments in the savanna, and the use of stable genotypes, capable of high seed yield is an important objective for sustainable production (Alghamdi, 2009). This is occasioned by high variability of climatic conditions in savannah zone which makes the production of high seed quality difficult. Evaluating new genotypes for ideal locations for seed production can make a substantial difference in yield and quality of seeds. Usually, locations with lower temperatures and dry conditions during preharvest can improve seed quality (Oliveira et al. 2021).
Literatures has reviewed those variations in environmental factors during the growing season and years influence soybean seed yield, quality, and its chemical composition (Wijewardana *et al*. 2019). Studies has established that variability in seed protein, oil, and fatty acid content of soybean when exposed to elevated temperature and high UV-B radiation (Reddy *et al*., 2016), and drought (Dornbos and Mullen, 1992, Rotundo and Westgate, 2009, Rotundo et al., 2009, Specht et al., 2001). The higher protein might be due to increased N, K, P, and B concentrations in leaf and seeds (Manju et al, 2012). They demonstrated that foliar application of K and Gly altered mineral concentration in leaves and shifted seed composition towards protein and stearic concentration. Nacer and Alemu (2008) working on soybean reported that irrigation management and cultivar selection significantly affect seed composition and yield.

The concern for yield and quality is essentially for the food reserves in the seed which could be influenced by the environment. Interest in soybean production in Nigeria has increased considerably over the past few decades. Soybean (*Glycine max* (L.) Merr.) production is on a large scale in Benue state – Nigeria. To date, the Benue State remains the most important location of soybean production in Nigeria (Fasusi *et al*., 2022). The selection of soybean varieties most suitable to agroecology is important to achieve higher yield and food security in Nigeria (Fasusi *et al*., 2022). Therefore, the introduction of adaptable cultivars will enhance productivity and help in the self-sufficiency of this vital commodity. The development of new cultivars with desired characteristics such as high economic yield, traits that add value to the product like biochemical components in specific environments will enhance their adoption. The interaction existing between genotypes and the different environments is one of the major impediments in the selection of competitive soybean genotypes for a wide range of cultivation as crop yield depends on the nutrient's intake from soil via plants in the form of cation or anion (Pandey and Kamboj 2022). There is need for the evaluation of promising genotypes across savanna agro ecological zones that provide stable and high yield for higher economic returns for farmers.

In order to satisfy the demand by consumers, some newly introduced soybean genotypes are evaluated for seed quality and agronomic characteristics and adaptability in Makurdi- Benue State. The essence is to produce soybean for targeted end-users in protein or oil related products. So, these genotypes were evaluated for physiological and biochemical seed quality traits.

Materials and Methods

Seeds of twelve genotypes of soybean were obtained from the National Cereal Research Institute (NCRI), Badeggi, Nigeria. Ten of these genotypes S1075-6-93, S1179-6-58, S1239-6-135, S1240-6-288, S1252-6-277, S1252-6-156, S1268-6-15, S1273-6-65, S1365-6L-20 and SC SENTINEL was newly introduced to Makurdi while SC SIGNA and SLO1 which has been released are used as checks. The seeds were multiplied at the Teaching and Research Farm of Joseph Sarwuan Tarkaa University Makurdi (latitude 7.7322^0N) and (longitude 8.5391^0). Seed samples were collected and subjected to seed quality tests (physiological and biochemical traits) at the Department of Plant Breeding and Seed Science Laboratory. The following tests were carried out;

Emergence Test: Hundred seeds were planted on moistened riverbed sand in plastic bowl in four replicates per genotype according to ISTA rules (ISTA, 1999). Emergence percentage (EPCT) was calculated by expressing the number of normal seedlings that emerged at 8 days after sowing as a percentage of the number of seed sown.
Emergence counts were taken at 3, 5, 7 and 8 days after planting according to ISTA rules for seed testing (ISTA, 1999) procedure for standard. The emergence percentage was substituted into the formula (Ajayi and Fakorede, 2000) to obtain emergence index (EI) in the laboratory

$$\text{Emergence percentage (EPCT)} = \frac{100 \text{ x Number of seedlings emerged 8DAS}}{\text{Total number of seeds planted}}$$

$$\text{Emergence index (EI)} = \frac{\sum \text{(number of plants emerged in a day) (DAS)}}{\text{Total number of plants that emerged on the } 8^{th} \text{ day}}$$

Seedling length**:** length of ten randomly selected seedlings of each genotype was measured in centimeter 8 days after germination.
Seedling vigor index**:** this was determined according to the procedure of (Sharma, 2018) as follows

SVI = emergence percentage x seedling length.

Seedling fresh weight (g): Ten seedlings were randomly sampled from each replicate at 8 days after sowing and were weighed using sensitive scale in grams.
Seedling dry weight(g): Ten seedlings were selected from each replicate at 8 days after sowing and oven dried at a temperature of 130^{oc} for 1hour, dry weigh of the sample was determined using a sensitive scale in grams in accordance with Adebisi *et al* (2011). The same samples were used for fresh and dry seedling weight.

Biochemical Analysis: (Proximate Analysis)
Seed sample from each genotype was used to determine percentage protein, oil, and ash in accordance with the standard procedures of Association of Official Analytical Chemists (AOAC, 1987). Seed sample of 10g per genotype was grinded and oil was extracted for 8 hours with petroleum ether using soxhlet apparatus. The extracted oil was dried at $80\text{-}90^{oc}$ using a hot air oven to remove the solvent. The flask was transferred to a desiccator, cooled and weighed. Ash content was determined by incineration in muffle furnace at 600^{o}c for 3 hours. Nitrogen content was calculated by

$$\%N = \frac{\text{Net volume of acid x 0.014 x 100 x Dilution factor 2.5}}{\text{Weight of seed sample in g}}$$

Crude protein was estimated by multiplying nitrogen concentration by a factor of 6.25 (100/16) for approximately 16% nitrogen in protein contains.
Statistical analysis: Data collected on all parameters were subjected to analysis of variance (ANOVA) using Statistical Tool CropStat and significant means were separated using least significant difference (LSD) at 5% probability.

Results and Discussion

The analysis of variance revealed significant differences in germination rate and germination rate index. Other traits (seed fresh weight, seed dry weight, root length, shoot length and seedling vigour index) were not significantly different (Table 1). Seed quality is not a single measurable property; which means many parameters or predictors could be used to assess it. Most of the times there are variations in sensitivity of these tests, a reason that calls for an alley of tests in order to determine their appropriateness under various conditions. SC SIGNAL had the highest germination rate index and significantly different from genotypes S1075-6-93, S1179-6-58, S1240-6-288, S1252-6-277 and S1365-6L-20. But not different from genotypes S1239-6-135, S1252-6-156, S1268-6-15, S1273-6-65, S1365-6L-20 and

SLO1 (Table 2). Similarly, SC SENTINEL had the highest germination index and is significantly different from genotypes (S1075-6-93, S1179-6-58, S1239-6-135, S1240-6-288, and S1252-6-277); but is of the same magnitude with genotypes (S1252-6-156, S1268-6-15, S1273-6-65, SC SENTINEL, SC SIGNAL and SLO1). There was no significant difference for the seedling traits across varieties. The differences in germination rate and germination rate index are indications of higher seed quality for those genotypes implicated. Higher ERI values indicates higher and faster germination while, higher EI values denote a higher rate of germination (Esechi, 1994 and Bench et al. 1991 and Kader, 2005).

Protein was highest in S1075-6-93, S1239-6-135 and S1252-6-156 with 40.25% crude protein and the least with SC SENTINEL having 37.19% (Table 4). Crude protein ranged between 40.25 to 37.19. Oil was highest in SC SENTINEL (20.82) and least in 1239-6-135 (18.83). Difference in percent protein in this study of 37.19 to 40.40.25 and oil content of 18.83 to 20.82 is comparable to the United States Department of Agriculture (USDA) food composition data which showed that soybean seeds contain 36.49% protein, 19.94% oil (Food Data [USDA], 2022). Ash content was highest in S1268-6-15 (5.40) and its least content was in S1240-6-288 with 4.43. moisture content was highest in S1365-6L-20 (9.90) and varieties (S1252-6-277 and S1273-6-65) had the least values of 8.31. 1179-6-58 had the highest Crude fibre while, SC SIGNAL had 3.15 only oil had a significant negative correlation with crude protein. There were no significant correlations among other seed compositions. Literatures reported a strong negative correlation between oil and protein accumulation has been observed in protein-storing seeds like soybean (Chung *et al*., 2003), as well as in oil- storing seeds like rapeseed (Grami *et al.*, 1977; Jolivet *et al.*, 2013), sunflower (Li *et al*., 2017) or the model plant Arabidopsis thaliana suggesting that seed filling in these species is highly constrained and that manipulating both components independently may be difficult as one increases the other decreases.

Others reported that protein and oil content cannot be separated in soybean (Chung *et al*., 2003) that the same genes are controlling both traits. However, QTL specific oil and protein contents were identified in rapeseed and Arabidopsis (Jasinski *et al.*, 2016), that protein and oil biosynthetic pathways could be separated. In this study, the decreases in oil content as protein content increases could be due to genetic make up which are reported to be significant for seed yield, protein, and oil (Wilcox and Shibles, 2001). Negative correlations existed in soybean seeds between protein content and oil content in this study; agrees with the findings of Patil *et al*. (2017) and Rincker *et al*. (2014). They reported that this inverse relationship has posed a challenge to increasing soybean protein content while maintaining the desired seed oil level and seed yield. Chathurika *et al*. (2019), in soybean, reported a negative correlation between seed protein and oil content. They attributed this to changes in nutrient accumulation and partitioning in soybean seeds under water stress. It was also reported that high temperatures can reduce protein content in favour of oil content (Nakagawa *et al*., 2018). These researchers also reported that high temperatures can reduce protein content in favour of oil content. Individual genotypes could have responded differently to the prevailing weather conditions as a result of their genetic make-up in respect to compartmentalization of seed reserves and this explains the variation in protein and oil contents. The three genotypes (S1075-6-93, S1239-6-135and S1252-6-156) with 40.25% protein have higher physiological potentials. Research has reviewed that seeds with higher protein-content have greater physiological potential and seeds with higher oil content are negatively associated with physiological potential (Capelin *et al*., 2022).

Conclusion

Biochemical components have more effect on the seed quality of these genotypes evaluated in Makurdi. Genotypes (S1075-6-93, S1239-6-135 and S1252-6-156) had higher protein content than the checks (Sc SIGNA and SL01). Also, Sc SENTINEL, S1365-6L-20, S1273-6-65, S1268-6-15 and S1240-6-288 had higher oil content than the checks. Those genotypes with high protein content could be used for protein-based products while SC SENTINEL with 20.82 percent protein could be used for oil production. This insight could influence the marketing opportunities of these soybean genotypes bearing in mind the need of the end users. Variations in protein and fat content in soybean seeds indicates that these genotypes could be improved with careful management practices. These genotypes could be incorporated into the soybean cropping system by farmers in Makurdi.

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Table 1. Analysis of variance showing sources of variation on physiological and seedling traits of twelve varieties of soybean in Makurdi

Sov	Df	G%	ERI	EI	SFW	SDW	RL	SHL	SVI
Genotypes	11	27.71	17.74**	.44**	1.62	.40	5.10	19.13	9114.2
Rep	2	18.77	0.53	.21	3.51	.68	.36	1.62	1691.13
Residual	22	28.23	5.21	.13	2.47	.33	3.78	18.67	35923.2

Key: G% = Germination percentage, GRI = Germination rate index, GI = Germination index, SFW = Seed fresh weight, Seed Dry Weight, Root length, SHL= Shoot Length and SVI = Seedling Vigour 1

Table 2. Means of selected varieties of soybean for physiological and seedling traits in Makurdi

Genotypes	E%	ERI	EI	SFW	SDW	RL	SHL	SVI
SC SIGNAL	90	35.66a	13.7a	5.62	1.4	5.87	19.8	531.47
SC SENTINEL	88.67	34.71a	13.72a	4.51	1	5.91	18	535.25
S1252-6-156	87.33	34.19a	13.58ab	3.76	0.87	6.04	23.03	531.73
SLO1	89.33	34.14a	13.43abc	6.65	2.03	6.3	18.43	562.67
S1273-6-65	90.67	33.38ab	13.29abc	5.17	1.23	4.55	18.59	413.15
S1239-6-135	94.67	32.72abc	12.96cd	5.41	1.5	8.65	17.7	817.6
S1268-6-15	88	32.67abc	13.47abc	4.57	1.27	5.84	20.13	516.32
S1252-6-277	90.67	31.59bc	13.06bcd	4.9	1.8	5.06	25.57	459.6
S1365-6L-20	87.33	31.16bc	13.18abcd	5.86	1.6	6.87	20.67	602.93
S1240-6-288	93.33	30.06bcd	12.6d	5.57	1.74	5.15	16.67	478.07
S1179-6-58	84.67	29.72bcd	12.95cd	5.12	1.57	4.36	19.87	367.68
S1075-6-93	84.67	27.19d	12.62d	5.07	2	3.63	17.57	311.87
SE	3.07	1.32	0.22	0.91	0.34	1.12	2.5	109.43
5% LSD	ns	3.87	0.63	ns	ns	ns	ns	ns

Key: E% =Emergenc percentage, GRI = emergence rate index, GI = Emergence index, SFW = Seed fresh weight, Seed Dry Weight, Root length, SHL= Shoot Length, SVI = Seedling Vigour 1 and ** = Significant at 0.01 probability level)

Table 3. A correlation showing the interplay of the various seed components of the selected genotypes of soybean in Makurdi

	CP	FAT/OIL	ASH	MOISTURE
FAT/OIL	-0.696**			
ASH	-0.336^{ns}	0.308^{ns}		
MOISTURE	0.323^{ns}	-0.146^{ns}	-0.212^{ns}	

CF	-0.028 ^{ns}	-0.008 ^{ns}	-0.357 ^{ns}	0.232 ^{ns}

Key: CP = Crude Protein, CF = Crude Fibre and ** = Significant at 0.01 probability level)

Table 4. Mean values from proximate analysis for selected soybean genotypes

Genotype	Crude Protein	Oil	Ash	Moisture content	Crude fibre
S1075-6-93	40.25	19.23	4.96	9.57	3.12
S1179-6-58	38.06	19.28	5.04	9.2	3.96
S1239-6-135	40.25	18.83	4.50	9.48	3.53
S1240-6-288	38.06	20.19	4.43	9.49	3.56
S1252-6-277	38.06	19.64	5.08	8.31	3.29
S1252-6-156	40.25	19.69	5.03	9.32	3.52
S1268-6-15	38.06	20.29	5.40	9.66	3.45
S1273-6-65	38.06	20.26	5.33	8.31	3.03
S1365-6L-20	38.06	20.25	5.1	9.90	3.33
SC SENTINEL	37.19	20.82	5.0	8.96	3.61
SC SIGNAL	38.06	19.46	5.23	9.39	2.93
SLO1	38.06	19.91	4.94	8.67	3.15