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Research Article

Adoption of Soya Bean (*Glycine max*) Elite Lines and Multivariant Analysis Based on Agronomic Traits: A Case of Agro-Ecological Region III of Zambia

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About Article

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ABSTRACT

Soya bean food system has been on the growing trajectory globally and in the sub-Saharan region. However, the pace of growth in this food-system within Zambia, has been slower compared to the regional growth and the global trend. Therefore, this study focused on evaluating the factors that affect the adoption of soya bean varieties within agro-ecological region III of Zambia. Furthermore, the study focused on identifying potential candidate parental lines among adopted soya bean varieties for crop improvement. The study incorporated 365 farmers and the logit model was utilized to identify factors associated with adoption of soya bean production. On-farm field trials, were conducted on five (5) sites within the study area, during 2023/2024 and 2024/2025 seasons to assess the yield performance of adopted soya bean varieties. Socio-economic factors such as income, age, experience, marital status, education, government policies, extension services, credit facilities, occupation and farmer associations, were identified to influence the adoption of soya bean varieties. Furthermore, soya bean variety Dina, significantly out-performed ($p < 0.05$) all the varieties in terms of average number of pods per plant, 100 seed weight, and total number of seeds per plant. Correlation analysis, indicated a significant association (0.94^{***}) between number of pods per plant and 100 seed weight, and similarities were observed in their association with other traits. Furthermore, seed yield indicated significant associations with some yield components. Through cluster analysis, two (2) major candidate parental lines were established for candidate crosses. Ultimately, this knowledge will guide efforts in breeding to create and utilize superior cultivars that offer high yields in a range of crop circumstances among soya bean farmers.

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1. INTRODUCTION

Soya bean (*Glycine max* L.) is one of the major leguminous crops grown globally for its protein and oil rich content. The crop is also very important in the agricultural farming systems, as it fixes nitrogen thereby improving the soil fertility of the farmland soils. Suffice it to say, the yield of soya bean in most of the developing countries including Zambia, has largely remained lower than expected (Kahenge, 2020). In most of the African countries, the yield of soya bean is below 1ton/ha against the potential yield of 4.5ton/ha (Mwila *et al.*, 2022a). The yield of soya bean is affected by many factors ranging from biotic to abiotic factors. Biotic factors may include insect and disease pressure while abiotic factors include droughts, floods, low soil fertility, extreme temperatures, acidity and alkalinity of the soils etc.

Soya bean adoption and diffusion has been studied in great detail lately by researchers in the agricultural and crop improvement areas (Lubungu *et al.*, 2013; Kahenge, 2020; Siamabele and Manda, 2024). It can be studied at two levels: the first is at the sector level and the other is at the individual farmer's level. If the unit analysis is an individual farmer, the emphasis is on the acceptance of technology (Dasgupta *et al.*, 2002). In crop adoption and production, the farmer's attitude toward using and the actual usage of a technology are addressed in the technology acceptance model (TAM) (Masrom, 2007). TAM has been used as the theoretical basis for many empirical studies of user technology acceptance (Adams *et al.*, 1992; Mathieson, 1991; Davis *et al.*, 1989; Davis, 1989). Furthermore, development of new soya bean varieties intended for farmer adoption and crop improvement falls into the two classes of innovation and diffusion of innovation model described by Robertson (1967), namely; continuous innovation and dynamically continuous innovation. These two innovation classes alter the product involved but do not completely establish a new product on the market. Given the innovation, the problem becomes that of diffusion. Hence, the need to understand the factors that significantly influence the adoption of soya bean elite varieties if the target is to effectively diffuse this technology.

Therefore, this study was carried out to investigate the rates of soya bean adoption and the factors that influence adoption of improved soya beans varieties among farmers. Besides, the study focused on characterizing the soya bean genotypes and identify potential candidate parents in the breeding of soya bean genotypes among the prominently adopted soya bean genotypes within Agro-Ecological Region III of Zambia.

2. LITERATURE REVIEW

To boost soya bean production, the Ministry of Agriculture (MoA) in Zambia through seed control and certification institute (SCCI), has facilitated the release of a number of improved soya bean varieties to farmers. The varieties are known to be high yielding, adaptable, quick maturing and tolerant to rust. Some of the elite lines released in the recent past include; Lukanga, Magoye, Zambezi, Spike, Safari, Kafue and Dina (Siamabele, 2019). Despite the varieties released over the past years, soya bean productivity at farm field level remains low (PW, 2023). Many studies have indicated that low adoption of improved varieties significantly contribute to low productivity of legume

food crops (Siyunda *et al.*, 2022; Mwila *et al.*, 2022a; Siyunda *et al.*, 2023; Makela *et al.*, 2025). Although some of the recently released improved soybean varieties were first introduced and promoted in Zambia by the SCCI of the MoA of Zambia (Mwila *et al.*, 2022b), no study has been conducted to document the adoption of improved soya bean varieties among smallholder farmers in the agroecological region III of Zambia. Besides, there is still a need to breed varieties that will be able to withstand the adverse effects brought about by climate change. However, this cannot be done without the information needed to show how the elite varieties being developed are being adopted among farmers in Zambia.

Breeding of soya bean varieties that are able to withstand the adverse effect brought about by climate change, is one of the ways that would potentially improve the soya bean yield across different regions. Zambia in particular, has less than fifteen (15) commercialized soya bean varieties. Due to the very small pool of commercialized varieties, farmers have little choice to pick which variety to grow amidst climate adverse effects.

Multivariate approach techniques such as cluster and principal component analysis have previously been employed to identify candidate parents to utilize in breeding crosses as parents. The stated methods, have the capacity to clearer state the distinctions that exists between or among the varieties under study.

3. METHODOLOGY

The study was conducted in Solwezi district (Solwezi Central Farm Block), North Western Province of Zambia (Figure 1). This district was purposively selected, because it is one of the districts where improved soya beans seed varieties technologies was introduced by The Seed Control and Certification Institute (SCCI) of the Ministry of Agriculture and Livestock (MAL) of Zambia (Siamabele, 2019). Besides, Solwezi district is among the largest producers of soya bean in Zambia. Solwezi district covers an area of 11,150 km². The location of the study site was on Latitude S 10°2'30.26688" and Longitude E 32°18'53.60976'. It falls in region III of Zambia Agro-ecological zone. Average annual rainfall received is above 1200mm.

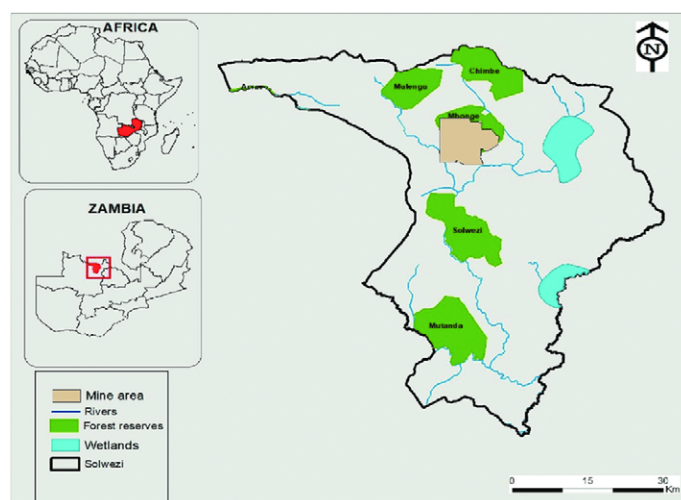


Figure 1. Map of Solwezi District
Source: Statoids (2010)



3.1. Study I (Survey)

3.1.1. Target population and sample size

The target population for this study was approximately 7203 registered and accessible small-scale farmers located in Solwezi District of North Western Province, Zambia. These farmers represented the primary focus of the research, as they were actively engaged in agricultural activities and played a crucial role in the local economy and food security. The target population included both farmers who adopted soya bean elite varieties and those who had been primarily engaged in monoculture cropping systems (non-adopters of soya bean elite varieties). Since the target population consisted of approximately 7203 small-scale, the desired sample size was calculated as below;

$$S = \frac{x^2 NP(1-P)}{d^2 (N-1) + x^2 P (1-P)}$$

Where S,

required sample size, x; Z – Score of 95% confidence level (1.96), N; Population size, P; Population proportion (assumed to be 0.5), d; Degree of accuracy expressed as a proportion (0.05).

Therefore, the sample size for this study was 365 small-scale farmers. By selecting 365 farmers of the population, the study aimed to capture a diverse range of perspectives and experiences among small-scale farmers regarding soya bean adoption and related factors.

3.1.2. Sampling procedure, research instruments, validity and their reliability

The sampling procedure for this study involved several meticulous steps aimed at ensuring the selection of a representative sample of small-scale farmers. Multi-stage sampling technique was employed, in which the selected district was divided into strata based on the agricultural sections/communities. Furthermore, 30% of the agricultural farming clusters in each study site (community) were chosen based on the soya bean production capacity. At the block level, 20% of the agricultural sections were selected and their selection was also based on their soya bean production capacity. At the farmer level, simple random sampling was employed, whereby farmers were chosen randomly from the sampling frame using methods such as a random number generator. The population was stratified into homogenous subgroups or strata based on these characteristics, and random samples were subsequently drawn from each stratum proportionally to its size.

For this study, a structured questionnaire was the sole research instrument utilized for data collection. The questionnaire was carefully designed to elicit relevant information from small-scale farmers in study sites. The questionnaire was divided into sections corresponding to the key variables of interest, including factors that influence farmers' decisions on adoption new technologies (e.g., elite varieties). To enhance the validity of the structured questionnaire, rigorous measures were undertaken throughout its development and administration process. Furthermore, the questionnaire underwent a pilot test involving a small subset of individuals representative of the target population. Feedback obtained from the pilot test informed necessary revisions to enhance the face validity of

the instrument. In this study, reliability was ensured through various strategies aimed at promoting consistency and stability in measurement. For instance, a subset of respondents completed the questionnaire on two separate occasions with a time interval in between, allowing for the assessment of test-retest reliability. Additionally, internal consistency reliability was evaluated for questionnaire sections containing multiple items measuring the same construct, using statistical measures such as Cronbach's alpha coefficient.

3.1.3. Data collection and analysis

To ensure inclusivity and accessibility, research assistants assisted participants who faced challenges with reading or writing in completing the questionnaire. This included reading out questions, explaining response options, and accurately recording responses. Efforts were made to create a conducive and respectful environment for data collection, encouraging participants to share their perspectives comfortably. The statistical package for Social Science (SPSS) version 20.0 was used to analyse the data. Upon completion of the data collection phase, the collected data were imported into SPSS for statistical analysis. The Logit (logistic) model was used to analyze factors that affect the adoption of elite soya bean varieties. Descriptive statistics was used to describe the socio-economic and demographic factors that affect the adoption of elite soya bean genotypes. The implicit form of regression model was given defined as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + U_i \quad \dots(1)$$

Where, Y= is the dependent variable under the dummy variable 1 if the farmer adopted elite soya bean varieties, or 0 if the farmer did not adopt soya bean varieties. X_1 = Income improvement, X_2 = Age of farmer, X_3 = Farmer Cultivation Experience, X_4 = Gender, X_5 = Marital status, X_6 = Education, X_7 = Government policies, X_8 = Extension access, X_9 = Access to agricultural inputs, X_{10} = Access to credit services, X_{11} = Size of land cultivated, X_{12} = Land ownership, X_{13} = Road status, X_{14} = Occupation, and X_{15} = Access to farmer association.

3.2. Study II (On-Farm field trials)

3.2.1. Research design and germplasm material

Experimental design used in the current research was randomized complete block design (RCBD) with five (5) soya bean genotypes considered as treatments each replicated three times. The five (5) genotypes used in this experiment included; Dina, Lukanga, Kafue, Zambezi, and Spike. The On-Farm field trials were established on five (5) sites/farms during two (2) planting seasons i.e., 2023/2024 and 2024/2025 farming seasons.

3.2.2. Agronomic practices

Well-suitable farm lands were selected where the research was conducted, and the necessary land preparation was done until the land became suitable for planting. Soil testing was done before the commencement of planting. Planting was done on 18th December, for 2023/2024 season and on 15th December for 2024/2025 and all the agronomic practices were timely done.

3.2.3. Population of the study/sample population

Each plot had 5 lines with the length of 5 meters. The inter row



spacing was 0.6 meters and intra row spacing was 0.15 meters with the plant population per experimental unit of 665 plants/plot. Systematic sampling method was utilized for the sampling procedure with a sample size of 40% from the net plot.

3.2.4. Data collection and analysis

From the date of planting, data was collected and physiological traits were collected which included; terminal leaf length, terminal leaf width, plant height, biomass, pods per plant, pod length, pod width, number of locules, ground cover, plant vigor, number of seeds per pod, plant density, 100 grain weight and yield per hectare. Plants were harvested to obtain statistics on both soya bean and its biological yield. The acquired data was summarized using excel, before being subjected to Analysis of Variance (ANOVA). ANOVA was performed at a significance level of 0.05 using R-programming statistical software.

4. RESULTS AND DISCUSSION

4.1. Study I

4.1.1. Socio-economic characteristics of soya bean farmers

Table 1 indicates the description of the farming community where the study was conducted. Out of the small-scale farmers engaged in the study, it was discovered that the maximum age of the respondents was 66 years old, while the minimum was 25-year-old. The average age of the respondents was 46 years. The findings of the current study are in tandem with the findings of Tanko *et al.* (2021), who stated that most of the new technologies in farming are adopted by middle aged farmers. Several studies have indicated that, the average age of 40-45 is an active age in farming that is more prone to adopting new technologies easily within farming systems (Idrisa, 2009; Kamara, 2009; Mbavai, 2013; Mignouna *et al.*, 2013; Ndaghu *et al.*, 2015). The average age of 46, is an indication that Solwezi district of Zambia has farming as one of the major drivers of people's livelihood. Besides, it also indicates the availability of active labour for farming operations.

A majority of farmers that indicated adoption of soya bean production were male headed households (88.77%) compared to female headed households (11.23%). The current findings are similar to the findings of Tanko *et al.* (2021). Tanko *et al.* (2021) indicated that a majority of the adopters and non-adopters of soya bean producers were male (92.8%) compared to females (7.2%). The findings of this study indicate that, the male gender dominates soya bean adoption as they were a majority. This may be attributed a lot of varying factors that predominately restrict the female gender in their farming communities.

A majority of the respondents were married (76.44%), followed by those that were widowed (20%). The least among them were the singles (0%). The study indicated that married respondents highly adopted soya bean production (91.75%) compared

to singles (0%). Besides, the survey showed that widowed respondents (77.0%) recorded a high adoption of soya bean production compared to divorced respondents (66.6%). The high adoption rate among married respondents may be attributed to a divergent and balanced view of technology adoption among farmers. This balanced view of technology adoption, tends to reduce into single oriented view in cases where the household is being parented by a single gender. Furthermore, this trend of technology adoption was observed in the scores between the divorced and widowed. The reduced adoption rate among the divorced and widowed respondents compared to the married, might be attributed to the reduction of the divergent and balanced view of technology adoption among the respondents. Education level indicated highly significant influence with regard to soya bean adoption among the small-scale farming within the study area. The study indicated that respondents who had not attended any level of education (1.92%) recorded the lowest level of soya bean adoption (17%) compared to respondents who had attended tertiary education, specifically certificate level (who indicated 100% soya bean adoption). The results in the current study correspondents with the findings of Ndaghu *et al.* (2015), who reported low rate of maize adoption among respondents who had attended no formal education level. An increasing trend of adopting new technologies from non-education attends to highly education attendees, in the farming systems has been observed by several researchers (Banabana-Wabbi, 2002; Jones, 2005; Muyanga, 2009; Kudi *et al.*, 2011; Ndaghu *et al.*, 2015). The high adoption rate of soya bean cultivation among farmers who attended formal education, may be attributed to the fact that, they easily understood the technology and adopted it within a short time compared to respondents who had not attended any formal education.

Respondents whose major occupation was farming, indicated a significantly high adoption rate of soya bean cultivation (99.58%) compared to the respondents having other streams of livelihood. However, the study observed that civil servants were among the least adopters of soya bean production (35.29%). The significant variation in the adoption rate of soya bean among respondents with different occupations, indicates variations in the way soya bean production technology was being perceived among the respondents (farming community). The highly significant adoption rate exhibited by respondents whose major occupation was farming indicates the possibility that these respondents had a positive and richer perception of the benefits of soya bean production compared to others. However, the significantly lower adoption rate of soya bean production exhibited by civil servants compared to others, might as well give an insight that not everyone has the same information concerning soya bean production among the farming community within Solwezi district of the Copperbelt province.

Table 1. Socio-economic characteristics of the survey participants

Characteristic	Categories	Adopters	Non-Adopters	Total Frequency N=365	Percentage
Age groups	Min			25	
	Max			66	
	Mean			46	



Gender	Male	289	35	324	88.77
	Female	32	9	41	11.23
Marital status	Single	0	0	0	0.0
	Married	256	23	279	76.44
	Divorced	8	4	12	3.29
	Widowed	57	17	74	20.00
Education level	Never been to school	1	6	7	1.92
	Primary	191	16	207	56.7
	Secondary	65	9	74	20.27
	College Certificate	6	0	6	1.64
	Diploma	23	7	30	8.22
	Degree or above	35	6	41	11.23
Occupation	Farmer	238	1	239	65.4
	Trader	23	17	40	10.7
	Civil servant	6	11	17	4.7
	Miner	44	10	54	15.9
	Business	3	2	5	0.7
	Others	7	3	10	2.7

4.1.2. Logits model results to determine the factors affecting adoption of soya bean varieties

The study looked at a myriad number of factors that could potentially affect the adoption of soya bean. Out of the proposed fifteen (15) variables assumed to be associated with the adoption of soya bean elite lines, only ten (10) variables indicated significance association (Table 2).

The study revealed that income improvement ($p=0.002$) was associated with the adoption of soya bean production within the farming community of Solwezi district (Table 2). The findings of this study are in tandem with the findings by Agbamu (2006). Agbamu (2006) stated that, the adoption of new farming technologies can be enhanced if the who would be adopters perceive that the technology to be adopter has the potential to improve their livelihood, income levels inclusive. Soya bean production is one of the area that the government of Zambia, through the ministry of agriculture, has been promoting under the crop diversification program. Besides, the observed high adoption rate is could be attributed to the fact that soya bean production has been proved to be more of a profitable enterprise compared to the tradition of cultivating maize within the Zambian farming systems.

Farmer cultivation experience ($p=0.000$) significantly affected the adoption of soya bean production. These findings are similar to the findings of Mamudu *et al.* (2012) in Ghana and Tanko *et al.* (2021) in Nigeria. In both cases, the researchers revealed that farming experience plays a major role in the adoption of new technologies. The observed pattern of adopting soya bean production indicated that, the farmers who had a longer farming experience easily adopted soya bean production than the farmers who had a shorter farming experience. This trend

might be because farmers with a longer farming experience had been exposed to a myriad number of farming technologies and thus could adopt new technologies easily than the farmers with a shorter farming experience. This is further supported by the significant effect that age of a farmer had on the rate of soya bean adoption as more than 66.7% of soya bean adopters were 35 years of age and above. Therefore, in the current study the researchers observed that, the older a farmer was, the more farming experience they gained and the more likely they could adopt new farming technologies such as soya bean production. Government policies significantly affected the adoption of soya bean production among small scale farmers ($p=0.017$). This could be seeing in the way soya bean farmers having different occupations adopted soya bean production. Farmers employed by the government (civil servants) had the lowest adoption rate of soya bean production followed by traders (57.5%). Similar observations were indicated in the study by Zalkuwi *et al.* (2015), whose study states that, government policies play a significant role in the adoption of new technologies in the farming communities. The significantly high adoption rate of soya bean production among farmers in Solwezi district might be attributed to good government policies that support the production of soya bean. However, the low adoption rate of soya bean production among respondents who work for the government of Zambia, may be attributed to the negative perception that these farmers have concerning government policies. This being the case, there is need for policy makers to further create policies that could support the adoption of new technologies in agriculture.

Access to extension service ($p=0.019$) and access to farmers' association ($p=0.001$) both significantly affected the adoption



of soya bean production. That makes these two platforms to be similar is their capacity to act as sources of information to the farming community. A high adoption rate (>73%) among farmers who had a high rate of access to extension service and access to agricultural association was observed. Similar findings were recorded by Gama (2013) and Ndaghu *et al.* (2015). According to Ndaghu *et al.* (2015), membership of farmers to any of the farming clubs or associations, has the potential to create flow of information within the network which could otherwise not be accessed if the farmer operated independently. The high rate of adopting soya bean production among farmers who had access to extension service and access to farmer association compared to farmers that did not have access to these facilities could be

attributed to the information provided by these platforms to farmers. The farmers with these facilities were to a greater extent advantaged in that, they had information concerning the benefits of soya bean production in terms of it being the potential source of income and the role it plays in the farming systems because of its nitrogen fixing ability. Similar, access to credit services significantly affected the adoption of soya bean production. Farmers who had an access to credit services were discovered to have a high adoption rate of soya bean production compared to farmers without access to credit services. Several researchers have indicated the importance of access to credit services for agricultural productivity (Idrisa, 2009; Ayayi & Solomon, 2010; Adesope *et al.*, 2012; Ndaghu *et al.*, 2015).

Table 2. Logits model results of factors associated with soya bean adoption

Variables in the equation	Model Coefficient	SE	Sig	Exponential of the model coefficient
Income improvement	0.183	0.657	0.002	1.927
Age of farmer	0.579	0.093	0.031	0.012
Farmer cultivation experience	0.818	0.196	0.000	0.211
Gender	0.115	0.015	0.061	0.445
Marital status	0.214	0.035	0.007	0.476
Education level	0.176	0.749	0.029	0.188
Government policies	0.112	0.083	0.017	1.297
Access to extension service	0.197	0.084	0.019	1.218
Access to agriculture inputs	0.325	0.278	0.152	0.254
Access to credit	0.312	0.092	0.001	1.367
Size of land cultivated	0.217	0.356	0.162	1.287
Land ownership	0.015	0.011	0.196	0.986
Road status	0.052	0.012	0.261	0.748
Occupation	0.002	0.005	0.023	1.002
Access to farmers association	0.114	0.014	0.001	1.212

4.2. Study II

The five (5) on-farm field trial sites, located across different farm blocks within Solwezi district, indicated significant differences

($p < 0.05$) in all the soil parameters except for electric charge (EC) (Table 3).

Table 3. Characteristics of soils across on-farm field sites

Soil Parameters	Site 1	Site 2	Site 3	Site 4	Site 5	LSD
pH (1-14)	5.37 ^{ac}	6.41 ^b	5.18 ^a	5.17 ^a	5.49 ^c	0.21
EC	0.12	0.16	0.14	0.22	0.17	ns
N (%)	0.76 ^a	0.34 ^b	0.89 ^a	0.17 ^b	0.28 ^b	0.21
P (mg/kg)	34.89 ^a	47.14 ^b	34.24 ^a	25.12 ^c	26.13 ^c	4.55
K (mg/kg)	56.97 ^{ab}	78.33 ^c	51.24 ^a	64.34 ^b	32.45 ^d	12.34
Organic Carbon (C%)	0.46 ^a	0.42 ^a	0.45 ^a	0.41 ^a	0.31 ^b	0.05
Soil textural class (USDA)	Clay loam	Loam	Sand clay loam	Clay loam	Sand clay	

Note: Means with the same superscripts are statistically similar while means with different superscripts are statistically different., ns; not significantly different., Site 1; located in St Francis Farm Block., Site 2; located in Mutanda Farm Block., Site 3; located in Lunga Farm Block., Site 4; located in Mushindamo Farm Block., Site 5; located in Mukumbi Farm Block.



Significant variations ($P<0.05$) were also observed in the performance of different soya bean genotypes across two (2) farming seasons in the two (2) parameters i.e., number of pods per plant and total number of seeds per plant. However, non-significant variations were identified in the other genotypes (Table 4). The performance of soya bean genotypes indicated variations ($P<0.05$) in different sites in 50% of the variables understudy. The variables that indicated significant variations in different sites included; number of main branches, number of leaves, leaf length, 100 seed weight, fresh shoot biomass, and number of nodules per plant. The findings in the current study with regards to seed yield per site, are in tandem with the findings of Radi *et al.* (1993) and Al-Assily *et al.* (2002). In both studies, five (5) soya bean genotypes were tried in different sites and years. The study by Radi *et al.* (1993), indicated significant variations in seed yield across different soya bean genotypes while the study by Al-Assily *et al.* (2002), indicated consistent high yielding seed performance in the three (3) genotypes; Giza 35, Giza 111 and H2L12 across different sites in different seasons. The variations in the soya bean performance across two (2) farming seasons and five (5) sites, might be attributed to the variations in the amount of rainfall that was received in each farming season and different soil properties possessed by different sites. Besides, other than the rainfall pattern and soil properties, other environmental factors might have potentially affected the performance of the soya bean genotypes.

Significant variations were observed ($\alpha=0.05$) in the performance of soya bean genotypes across all the parameters under study, except for fresh root biomass (FRB) and number of nodules per plant (NPP), were non-significant variations were recorded ($P>0.05$). The analysis of variance (Table 3) indicated significant variations ($P<0.001$) among soya bean genotypes in terms of; average number of main branches per plant, average number of leaves per plant, average leaf length, average terminal leaf length, average terminal leaf width, average pod length, average number of pods per plant, 100 seed weight, total number of seeds per plant, and fresh shoot biomass. However, the analysis of variance for variables such as fresh root biomass and number of nodules per plant, indicated non-variations ($P>0.05$) among soya bean genotypes (Table 3 and 4). Soya bean genotype Dina, significantly outperformed ($P<0.05$) all the varieties understudy in terms of number of main branches per plant, average leaf length, average terminal leaf width, average number of pods per plant, 100 seed weight, total number of seeds per plant and fresh shoot biomass.

However, soya bean genotype Lukanga, was statistically at par with Dina in terms of average number of leaves per plant while soya bean genotype Zambezi, was at par with Dina in terms of average pod length. Soya bean genotype Zambezi, outperformed all the other soya bean genotypes in terms of average terminal leaf length (10.43 cm) and average terminal leaf width (5.77 cm). The performance of Zambezi, in other parameters such as average pod length and average number of pods per plant was extremely well and significantly higher, compared to other genotypes. Zambezi recorded the average pod length of 4.67cm, though statistically at par with Dina at 4.77 cm and it recorded the average number of pods per plant of 83pods/plant, though statistically at par with spike at 79 pods/plant. Total number of seeds per plant was significantly ($P<0.05$) higher in Dina (515 seeds per plant) followed by Zambezi with a record of 248 seeds per plant. Soya bean genotype Lukanga, outperformed all the other soya bean genotypes in terms of average number of leaves per plant by recording 85.9 leaves per plant, though statistically at par with Dina (85.24 leaves per plant). In terms of average leaf length and 100 seed weight, Lukanga recorded 10.47 cm and 18.89g respectively. The performance of Lukanga, in terms of average leaf length and 100 seed weight was statistically at par with Zambezi. Both genotypes (Lukanga and Zambezi) were statistically at par, but below the performance of Dina in the two (2) parameters (average leaf length and 100m seed weight.). Though non-variations were observed across all genotypes, in terms of fresh root biomass and average number of nodules per plant, suffice to say, Lukanga recorded the highest reading in terms of number of nodules per plant (Table 5). The variations observed in the performance of different soya bean genotypes, may be attributed to the differences in their genetic make-up.

The performance revealed by Dina and in some instances Zambezi and Lukanga, agree with the statement by Allard and Bradshaw (1964) and Deka and Talukder (2002). Allard and Bradshaw (1964), indicated that the best soya bean genotype reveals consistence with regards to higher yields across different sites and seasons. Irregardless of the year and site, Dina exhibited high stability in its yield performance among different genotypes. Furthermore, the performance of Dina and other genotypes agree with the statement of Beaver and Johnson (1981). Beaver and Johnson (1981) noted that, soya bean genotypes that indicate stability with regards to different sites are more suitable for adaptation cross different environments.

Table 4. ANOVA at alpha 0.05 for different parameters

SV	NMB	NL	LL	TLL	TLW	PL	NPP	100 SW	TNSP	FSB	FRB	NNP
Y	0.35	12.43	4.29	3.23	0.02	0.12	1.13*	3.45	111.21**	1.19	1.29	23.1
S	0.67*	9.86*	3.11*	1.97	0.11	0.34	1.89	2.89*	67.45	10.43*	3.48	11.23**
BL	0.08	369.38	0.69	1.67	0.69	0.05	27.16	2.24	1838.61	143.25	8.73	82.81
Gen	3.70**	1341.20**	8.13**	13.10*	3.89*	1.69**	6710.51***	31.92**	71631.70***	6128.61**	40.87	50.28
Y*S	3.49	4.33	5.39	2.83	0.25	5.67	11.29	2.89	2.58	2.95	4.25	7.89
Y*Gen	4.39	3.29	3.22	2.09	0.17	4.39	34.29**	23.19*	32.33*	3.02	3.59	10.23
S*Gen	3.29	2.37	1.98	0.45	0.99	3.94	1.36	11.89	1.92	34.22*	22.18**	2.34*



Y*S*Gen	23.1*	34.2	0.56	0.36	1.82	2.78	2.89	2.75	1.78	23.49**	1.27	3.28
Error	0.40	263.01	0.84	3.22	0.64	0.14	322.54	2.77	2935.25	484.76	12.87	18.70

*** Significant at $p \leq 0.001$, ** Significant at $p \leq 0.01$, * Significant at $p \leq 0.05$; Y; year, S; site; SV; source of variation, BL; block, Gen; genotype, NMB; average number of main branches, NL; average number of leaves, LL; average leaf length, TLL; average terminal leaf length, TLW; average terminal leaf width, PL; average pod length, NPP; average number of pods per plant, 100 SW; 100 seed weight (g), TNSP; total number of seeds per plant, FSB; average fresh shoot biomass, FRB; average fresh root biomass, NNP; average number of nodules per plant.

Table 5. Posthoc Analysis at alpha 0.05

Genotypes	NMB	NL	LL	TLL	TLW	PL	NPP	100 SW	TNSP	FSB	FRB	NNP
Lukanga	3.57 ^a	85.90 ^a	10.47 ^a	7.03 ^a	3.27 ^a	3.20 ^a	65.70 ^a	18.89 ^a	148.88 ^a	90.77 ^a	9.17	13.00
Zambezi	4.43 ^a	62.23 ^b	10.30 ^a	10.43 ^b	5.77 ^b	4.67 ^b	82.43 ^b	18.33 ^a	247.11 ^b	108.44 ^b	6.37	8.22
Spike	4.37 ^a	56.77 ^b	11.53 ^b	7.23 ^a	3.97 ^a	3.23 ^a	79.00 ^{ab}	16.69 ^b	177.55 ^a	96.13 ^{ab}	8.29	11.48
Kafue	3.47 ^a	35.57 ^c	8.87 ^c	4.70 ^a	2.80 ^a	3.90 ^c	51.43 ^a	16.62 ^b	150.89 ^a	77.60 ^a	5.97	2.82
Dina	6.23 ^b	85.24 ^a	13.30 ^d	6.33 ^a	4.30 ^c	4.77 ^b	171.80 ^c	24.58 ^c	515.00 ^c	191.22 ^c	15.15	11.67
CD	1.24	7.27	0.67	2.78	1.01	0.46	15.97	1.36	78.92	13.18	ns	ns

Note: Figures with the different superscript are statistically different while figures with the same superscript are statistically different. Key: ns; not statistically significant, SV; source of variation, BL; block, Gen; genotype, NMB; average number of main branches, NL; average number of leaves, LL; average leaf length, TLL; average terminal leaf length, TLW; average terminal leaf width, PL; average pod length, NPP; average number of pods per plant, 100 SW; 100 seed weight (g), TNSP; total number of seeds per plant, FSB; average fresh shoot biomass, FRB; average fresh root biomass, NNP; average number of nodules per plant.

4.1.3. Correlation analysis between soya bean growth and yield components

Table 6 indicates the association of different parameters across different genotypes. Average terminal leaf length and average terminal leaf width recorded the highest non-significant associations with other parameters under study. Average terminal leaf length recorded non-significant associations with all the parameters except with terminal leaf width. The non-association of terminal leaf length with all the other parameters is an indication that terminal leaf length does not play any significant role in the growth and development of the other parameters under study. However, average terminal leaf length had a significant association ($r = 0.90^{***}$) with average terminal leaf width, indicating that across genotypes, average terminal leaf length influences the growth and development of average terminal leaf width positively. The relationship of average terminal leaf length and average terminal leaf width is significantly demonstrated in the soya bean genotypes, Zambezi and Kafue (Table 6). On the other hand, average terminal leaf width indicated a significantly positive association with pod length ($r = 0.63^*$). Across soya bean genotypes, terminal leaf width indicated a positive influence on the length of soya bean pods. This insightful association may imply, the improvement of average terminal width would positively affect the length of soya bean pods, this is due to the positive association between these two parameters expressed by all genotypes.

Average number of leaves and average leaf length per genotype exhibited a significant positive association ($r = 0.68^*$). Both parameters revealed similarities in the associations they formed with other parameters (Table 6). Across different soya bean genotypes, average number of leaves per plant, indicated

a positive influence in the length of the leaf of soya bean plants. This insightful association may imply, trait association between average number of leaves per plant and average leaf length per genotype. Furthermore, the trait association between average number of leaves and average leaf length per genotype offers an insightful base into the genes that control both traits. Therefore, the improvement of average number of leaves per genotypes, would positively affect the average length of soya bean leaves per plant as well.

Part of the yield components under focus were, number of pods per plant and 100 seed weight. A highly significant association ($r = 0.94^{***}$) was observed between these two (2) parameters. Hundred (100) seed weight had a significant positive relationship with total number of seeds per plant (0.94^{***}), fresh shoot biomass (0.96^{***}), fresh root biomass (0.93^{***}), and number of nodules per plant (0.46^*). Similar trends of associations were observed between number of pods per plant and parameters such as total number of seeds per plant (0.98^{***}), fresh shoot biomass (0.99^{***}), fresh root biomass (0.92^{***}), and number of nodules per plant (0.44^*). The significantly high correlation between number of pods per plant and 100 seed weight and their similar behaviour exhibited between these parameters and other variables might be attributed to gene association controlling both traits. Furthermore, the current findings with regards to seed yield and its significantly high association with yield components, are in tandem with the finds of Ali (1993). However, they are different with the findings of Bekheit (2000). Bakheit (2000) indicated that, high yielding soya bean genotypes were more likely to have lower stability. The current study revealed that soya bean genotype Dina, though high yielding across different sites, its stability was above average compared to other genotypes.



Table 6. Correlation matrix

Variables	NMB	NL	LL	TLL	TLW	PL	NPP	100 SW	TNSP	FSB	FRB	NNP
NMB												
NL	0.51 [*]											
LL	0.91 ^{***}	0.68 [*]										
TLL	0.11 ^{ns}	0.25 ^{ns}	0.08 ^{ns}									
TLW	0.46 [*]	0.22 ^{ns}	0.32 ^{ns}	0.90 ^{***}								
PL	0.66 [*]	0.09 ^{ns}	0.31 ^{ns}	0.29 ^{ns}	0.63 [*]							
NPP	0.98 ^{***}	0.59 [*]	0.91 ^{***}	0.01 ^{ns}	0.35 ^{ns}	0.63 [*]						
100SW	0.87 ^{**}	0.73 ^{**}	0.81 ^{**}	-0.04 ^{ns}	0.24 ^{ns}	0.61 [*]	0.94 ^{***}					
TNSP	0.97 ^{***}	0.52 [*]	0.82 ^{**}	0.02 ^{ns}	0.38 ^{ns}	0.75 ^{**}	0.98 ^{***}	0.94 ^{***}				
FSB	0.97 ^{***}	0.61 [*]	0.88 ^{**}	0.02 ^{ns}	0.36 ^{ns}	0.67 [*]	0.99 ^{***}	0.96 ^{***}	0.99 ^{***}			
FRB	0.85 ^{**}	0.74 ^{**}	0.91 ^{***}	-0.21 ^{ns}	0.04 ^{ns}	0.33 ^{ns}	0.92 ^{***}	0.93 ^{***}	0.87 ^{**}	0.91 ^{***}		
NNP	0.39 ^{ns}	0.87 ^{**}	0.72 ^{**}	0.29 ^{ns}	0.21 ^{ns}	-0.23 ^{ns}	0.44 [*]	0.46 [*]	0.29 ^{ns}	0.41 [*]	0.59 [*]	

*** significant at $p < 0.001$, ** significant at $p < 0.01$, * significant at $p = 0.05$, ns; not significant, NMB; average number of main branches, NL; average number of leaves, LL; average leaf length, TLL; average terminal leaf length, TLW; average terminal leaf width, PL; average pod length, NPP; average number of pods per plant, 100 SW; 100 seed weight (g), TNSP; total number of seeds per plant, FSB; average fresh shoot biomass, FRB; average fresh root biomass, NNP; average number of nodules per plant.

4.1.4. Cluster analysis

Cluster analysis of the soya bean genotypes understudy indicated total variations at the rescaled distance of 1 unit and total similarities at the rescaled distance of 25 units (Figure 1). However, between 1 to 25 rescaled distance units, other unit levels gave rise to different clusters. Genotypes were resolved into two main clusters of A and B, with cluster A further dividing into sub-clusters A.1 and A.2. At the rescaled distance of 1 unit, total variations were observed in the genotypes, in which all the soya bean genotypes individually got isolated due to their genetic variations. It is worth noting that cluster A consisted of 80% of the soya bean genotypes while cluster B had only 20%. The genotypes under cluster A varied significantly from the genotypes under cluster B.

In the present study, two (2) main clusters and two (2) sub-clusters were identified as potential sources of candidate crosses. In terms of growth and development components such as number of main branches and average leaf length and also yield and yield components such as number of pods per plant, 100 seed weight, total number of seeds per plant and fresh shoot biomass, Stream A and B genotypes would be a good source of genes that can be utilized to improve soya bean in the stated variables. The genotypes under stream A.1 and A.2 can be classified as potential parents if improvement in the terminal leaf length, terminal leaf width and pod length are the breeding focus.

5. CONCLUSION

The study concluded that, a myriad number of socio-economic factors influence the adoption of soya bean elite lines. These factors include; income, age of the farmer, farmer cultivation

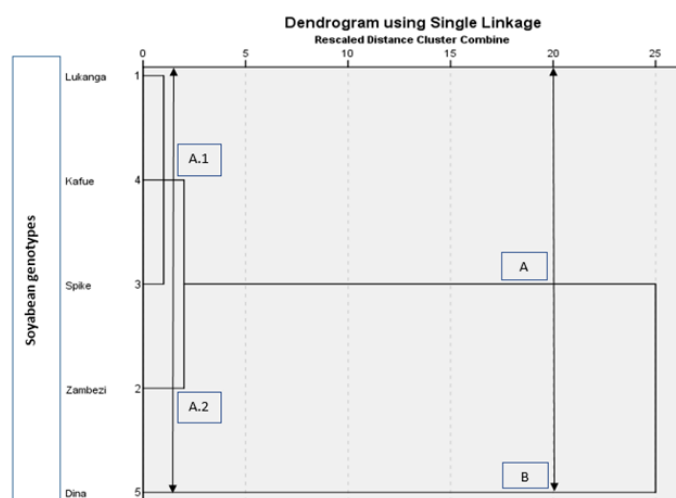


Figure 1. Similarities among the soya bean genotypes based on the phenotypic growth, development and yield components and grain yield.

experience, marital status, education level, government policies, access to extension services, access to credit facilities, occupation and access to farmer association. Developing and adopting high yielding soya bean lines is the best approach to improve the soya bean agri-food system. Thus, genotypes from stream A and B can be incorporated into the breeding programs to produce high yielding soya bean cultivars that can stimulate adoption of soya bean elite varieties among farmers. Ultimately, this knowledge will guide efforts in breeding to create and utilize superior cultivars that offer high yields in a range of crop circumstances among soya bean farmers.



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