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Evaluation of grains and haulms production of soybean varieties in production areas with high livestock potentiality in Benin

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ABSTRACT

Soybean is an important source of plant protein for animal and human feeding. The objective of the study was to determine the grain and haulm production aptitudes of soybean varieties TGX 1910-10F, TGX 1910-14F, TGX 1448-2D, TGX1830-20E and JENGUMA in the Agricultural Development Poles (PDA) with high livestock potentiality. An experimental design of six elementary plots of 400 m², each occupied by a soybean variety, was installed at 36 growers equally distributed in PDA 2, 3 and 4. Data on production were collected and an analysis of variance was performed in R software with the factor variety. Soybean grain yields of TGX1910-14F, TGX1910-10 F, TGX1448-2D, TGX1830-20E and JENGUMA did not vary between PDA. TGX1830-20E and JENGUMA had similar haulm production in PDA 2 and 4 and higher than PDA 3. In all three PDA, grain yields of TGX1910-14F were significantly higher than those of TGX1830-20E, JENGUMA and peasant varieties (p<0.001) which were similar while TGX1910-10F and TGX1448-2D had intermediate yields. For haulm, JENGUMA yield was higher (p<0.001) than the five other varieties which had similar yields. Within the three PDA, TGX1910-14F is better for grain production, followed by TGX1910-10F and TGX1448-2D, while JENGUMA is better for haulm production. These results offer opportunities for choosing soybean varieties based on the desired livestock product before studies on the contribution of the varieties to animal feeding would be carried out.

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INTRODUCTION

The agricultural sector is the primary source of wealth for Benin's people and employs a significant proportion of the population. Agriculture contributes an average of 27% to the national Gross Domestic Product (GDP), represents approximately 76% of export earnings, and provides nearly 16.3% of state revenue, while ensuring food security for the population (DSA, 2024). The agricultural activities cover several sectors, including meat, milk, eggs, and soybean, which are considered priorities for promotion in Benin.

In fact, soybean is an important source of plant-based protein for both human and animal consumption. Its grains are used directly or after processing in various forms. Many products come from soybean processing, such as mustard, flour, cheese, and milk (Michaud and Vodouhè, 2012). Soybean meal is the main protein-rich material used in animal feed (Ez-zayani, 2014), particularly in poultry farming.

Beyond the grains, soybean haulms are also used in ruminant feeding. They are given as a dietary supplement or used in the production of complete feeds such as multi-nutritional feed blocks. In addition, soybean improves soil fertility by fixing atmospheric nitrogen (Giller 2001).

Due to its importance, soybean production in Benin is experiencing a growing trend over time, increasing from 178,185 tons in 2018 to 520,929 tons in 2023, with an average national yield of 1,004 kg/ha of soybean grains (DSA, 2024). It has benefited from several studies aimed at optimizing its productivity for better use in human food, animal production, and for the resilience of the production systems facing climate variability and change. Benin's soybean seed systems were analyzed to enable the strengthening of the sector and producers' access to quality seeds (Ayenan *et al.*, 2017). The use of *Rhizobium*-based inoculum has been tested to improve grains and biomass yields. The effectiveness of *Bradyrhizobium japonicum* strains and the application of different phosphorus and nitrogen doses in soybean production have been tested (Houngnandan *et al.*, 2009; Zoundji *et al.*, 2015a). In addition, opportunities for promoting the soybean sector have been analyzed (Akplogan *et al.*, 2009). For example, soybean cheese processing processes have been evaluated to assess and improve their quality (Mètohoué *et al.*, 2009). Methods for processing soybeans into various products have been developed and technical guidebooks produced (Helvetas-Bénin, 2011). Studies have addressed the substitution of milk with soybean milk in various products including yogurt (Bokossa *et al.*, 2011). Later, a diagnostic study of soybean processing technologies into milk and derived products was carried out (Houssou *et al.*, 2015). The determinants of soybean yield and production systems were analyzed (Zoundji *et al.*, 2015b; Ollabodé *et al.*, 2017b).

Recently, the effectiveness of inoculums from three different origins was tested by Yaoïtcha *et al.* (2022) and revealed that the Nodumax, Bactigrow and Bio fertilisant inoculums give similar results. Bonou *et al.* (2025) tested the effectiveness of four mineral fertilizer formulas on soybean seeds inoculated or not with *Rhizobacteria* namely NPK 10.20.10, NPK 10.25.20, TSP + KCl and TSP + KCl + Urea on the TGX1910-14F soybean variety. They reported that the application of NPK 10.25.20 and NPK 10.20.10 fertilizers in particular and of TSP + KCl + Urea on inoculated seeds improve soybean productivity with the best results with NPK 10.25.20. These authors obtained soybean grain yields of 1567.7±790.5 kg/ha compared to 813.6±464.3 kg/ha for peasant practice.

Besides, different soybeans varieties are produced in the production areas across the country.

The major production areas are the townships of Collines, Borgou, Alibori, Donga and Atacora departments located in the PDA 2, 3 and 4, which are areas with high livestock potentiality. At the end of the 2023-2024 agricultural campaign, soybean grain production in these PDA were 109,893 tons for PDA 4, 104,082 tons for PDA 2 and 25,568 tons for PDA 3 (DSA, 2024). However, the agroecological situation is not the same in the areas. Benin has eight agroecological zones whose agricultural specificities have given seven Agricultural Development Poles. Differences in biotic and abiotic conditions might differently influence the grain or haulm productivity of soybean varieties. The rational use of the available varieties requires the identification of the most productive variety for each production and breeding pole.

Therefore, this study was initiated to evaluate the agronomic performance of soybean varieties in production areas with high livestock potentiality (PDA). Specifically, the aim was to determine:

1. Grain and haulm yields of soybean varieties according to the Agricultural Development Poles;
2. Grain and haulm yields according to soybean varieties in the Agricultural Development Poles.

MATERIALS AND METHODS

Study area

The study was carried out in Central and Northern regions of Benin at the Research-Development (R-D) sites of Badou (Gogounou) and Kokey (Banikoara) in PDA 2, Kouya (Boukoumbé) and Pingou (Matéri) in PDA 3, and Ouénou (N'dali) and Gbanlin (Ouèssè) in PDA 4. This study area is characterized by a Sudano-Guinean climate with a dry season from November to May and a rainy season from June to October.

Plant material

The plant material consisted of five experimental soybean varieties, namely TGX1910-14F, TGX1910-10 F, TGX1448-2D, TGX1830-20E, and JENGUMA, and one farmer/ peasant variety from each site that served as a control. It has been considered as farmer/ peasant variety, the variety that the grower had been using for at least four years, that did not come from the official seed system, and whose name was unknown to the grower.

Experimental design, growers' selection, technical operations and data collection

The experimental design was a six-treatment complete randomized block design, where each variety constituted a treatment occupying a 400 m^2 elementary plot. The elementary plots in the block were separated by 1 m wide alleys. Each grower represented a replicate. Six (06) producers were selected from each of the six sites based on accessibility, for a total of twelve (12) producers per PDA and thirty-six (36) for the study. The trial was carried out following the same procedure at all sites.

Soybean seeds were sown at 0.20 m x 0.50 m spacings with 2-3 seeds per pocket. Each plot was fertilized with 100 kg/ha of NPK and 50 kg/ha of urea 15 days and 45 days after sowing, respectively. Agronomic data on grains and haulms production were collected at the harvest to determine grain and haulm yields.

Statistical analysis

The collected data were analyzed using R statistical software, version 64.4.0.5. An analysis of variance was performed with the PDA as the source of variation in the study environment and the variety as the factor of variation within each PDA. The means obtained were structured using the SNK test.

RESULTS

Production of soybean varieties in farming area in central and northern Benin

For the entire study area, the grain yield trends of soybean varieties TGX1910-14F, TGX1910-10 F, TGX1448-2D, TGX1830-20E, and JENGUMA are shown in Fig. 1. TGX1910-14F had the highest yield, followed by TGX1910-10F, TGX1448-2D, TGX1830-20E, and JENGUMA, respectively, which had almost the same grain yield as the farmer/ peasant variety (VP).

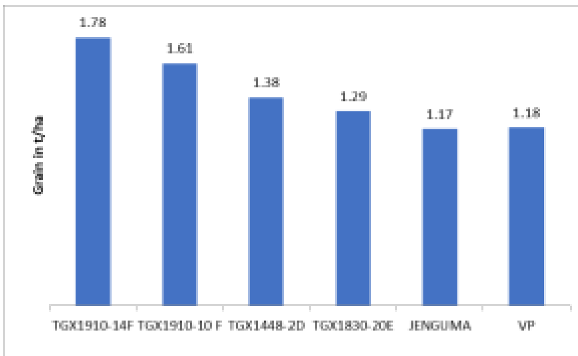

Fig. 1. Grain yields of soybean varieties in a farming area

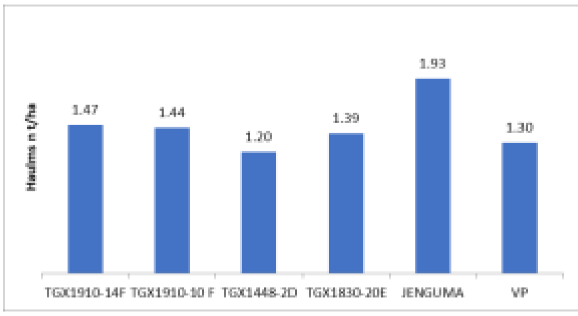

Fig. 2. Haulm yields of soybean varieties in farming area

Regarding soybean haulm, the higher trend was observed for JENGUMA, followed by TGX1910-14F, TGX1910-10F, TGX1830-20E, and TGX1448-2D varieties, respectively (Fig. 2).

Variation in grain and haulm yields of soybean varieties by agricultural development pole

The soybean grain yields obtained by Agricultural Development Poles (PDA) 2, 3, and 4 for the varieties TGX1910-14F, TGX1910-10F, TGX1448-2D, TGX1830-20E, and JENGUMA are presented in Table 1. These yields did not vary significantly from one PDA to another.

Table 1. Variation in grain yield of soybean varieties by agricultural development poles 2, 3, and 4

Variety	Grain PDA2 (t/ha)		Grain PDA3 (t/ha)		Grain PDA4 (t/ha)		Significativity
	Average	SE	Average	SE	Average	SE	
TGX1910-14F	1.79a	0.09	1.76a	0.09	1.79a	0.08	NS
TGX1910-10 F	1.59a	0.10	1.62a	0.11	1.62a	0.09	NS
TGX1448-2D	1.37a	0.11	1.37a	0.10	1.39a	0.09	NS
TGX1830-20E	1.29a	0.10	1.27a	0.10	1.31a	0.09	NS
JENGUMA	1.18a	0.08	1.16a	0.08	1.17a	0.07	NS

SE : Standard Error ; PDA : Agricultural Development Pole ; NS : $p>0.05$

Table 2. Variation in haulm yield of soybean varieties according to agricultural development poles 1, 2 and 3

Variety	Fanes PDA2 (t/ha)		Fanes PDA3 (t/ha)		Fanes PDA4 (t/ha)		Significativity
	Average	SE	Average	SE	Average	SE	
TGX1910-14F	1.67b	0.09	1.12a	0.03	1.59ba	0.09	**
TGX1910-10 F	1.67b	0.14	1.08a	0.05	1.56ba	0.14	*
TGX1448-2D	1.32b	0.09	1.02a	0.03	1.26ba	0.08	**
TGX1830-20E	1.62b	0.10	1.01a	0.04	1.51b	0.11	*
JENGUMA	2.28b	0.07	1.31a	0.05	2.16b	0.11	*

SE : Standard Error ; PDA : Agricultural Development Pole ; * : $p<0.05$; ** : $p<0.01$

Table 3. Variation in grain yields according to soybean varieties in agricultural development poles 1, 2 and 3

PDA	Grain (t/ha)	TGX1910-14F	TGX1910-10 F	TGX1448-2D	TGX1830-20E	JENGUMA	VP	Significativity
2	Average	1.79c	1.59bac	1.37bac	1.29ba	1.18a	1.18a	***
	SE	0.09	0.10	0.11	0.10	0.08	0.09	
3	Average	1.76c	1.62bac	1.37bac	1.27ba	1.16a	1.16a	***
	SE	0.09	0.11	0.10	0.10	0.08	0.09	
4	Average	1.79c	1.62bac	1.40bac	1.31ab	1.18a	1.20a	***
	SE	0.08	0.09	0.09	0.09	0.07	0.08	

SE : Standard Error ; PDA : Agricultural Development Pole ;*** : $p<0.001$; VP : Peasant/farmer variety

Table 4. Variation in haulm yields according to soybean varieties in agricultural development poles 1, 2 and 3

PDA	Haulm (t/ha)	TGX1910-14F	TGX1910-10 F	TGX1448-2D	TGX1830-20E	JENGUMA	VP	Significativity
2	Average	1.67a	1.67a	1.32a	1.62a	2.28b	1.46a	***
	SE	0.09	0.14	0.09	0.10	0.07	0.16	
3	Average	1.12a	1.08a	1.02a	1.01a	1.31a	1.03a	NS
	SE	0.03	0.05	0.03	0.04	0.05	0.03	
4	Average	1.59a	1.56a	1.26a	1.51a	2.16b	1.39a	***
	SE	0.09	0.14	0.08	0.11	0.11	0.14	

SE : Standard Error ; PDA : Agricultural Development Pole ;*** : $p<0.001$; $p>0.05$; VP : Peasant/farmer variety

On the other hand, significant differences were observed for the haulm yields (Table 2) of the different soybean varieties. Indeed, the haulm yields of TGX1830-20E and JENGUMA soybean varieties were similar for PDA 2 and 4 with higher values than those obtained in PDA 3 ($p<0.05$). This same trend was observed for TGX1910-14F, TGX1910-10F and TGX1448-2D varieties except that haulm yields of PDA 3 and 4 were not significantly different.

Variation in grain and haulm yields of soybean varieties in agricultural development poles 2, 3 and 4

The grain yields of TGX1910-14F, TGX1910-10F, TGX1448-2D, TGX1830-20E, JENGUMA and the farmer variety (VP) are given in Table 3. In PDA 2, 3 and 4, the grain yields of TGX1910-14F were significantly higher than those of TGX1830-20E, JENGUMA and farmer varieties ($p<0.001$) which were similar. Meanwhile, TGX1910-10F and TGX1448-2D had intermediate yields statistically identical to those of the first four varieties.

Regarding haulm yields, the production of JENGUMA variety was higher ($p<0.001$) than those of TGX1910-14F, TGX1910-10F, TGX1448-2D, TGX1830-20E and peasant variety which were similar. However, this difference was not significant in PDA 3.

DISCUSSION

Production of soybean varieties in farming area in central and northern Benin

For the entire study area, TGX1910-14F have the highest grain yield, followed by TGX1910-10F, TGX1448-2D, TGX1830-20E, and JENGUMA. Thus, whether in northern or central Benin, TGX1910-14F have the highest grain production potential, at 1.78 t/ha. This result confirms the higher grain yield potential of TGX1910-14F, as mentioned in the Beninese Catalogue of Plant Species and Varieties (MAEP, 2016). However, this variety's potential of 2.5 t/ha is not reached yet. On the other hand, the yield obtained for TGX1830-20E is low compared to its potential which is also 2.5 t/ha (MAEP, 2016). The difference in the grain production potential observed for these varieties must be linked to their cycle differences.

The cycle of the TGX1910-14F which is 115 days is more compatible with the climatic conditions of the period and allowed it to better express its grain yield than the TGX1830-20E which has a 95-day cycle.

In addition, the grain yield obtained in our study for TGX1910-14F is higher than those reported by Yaoïtcha *et al.* (2022) for the same variety in a peasant area in Bembéréké, N'dali and Nikki under conditions of use of Nodumax, Bactigrow and Biofertilisant inoculums.

These authors obtained a grain yield varying between 0.87t/ha and 1.10t/ha for soybeans inoculated without providing mineral fertilizer. The grain yield of the peasant variety (1.18t/ha) obtained in our study is significantly higher than the national average soybean yield which is 1004 kg/ha for the 2023-2024 agricultural campaign (DSA, 2024). Thus, the peasant variety is not unworthy and this performance is due to the fact that it may be an improved variety held by the growers for several years. Overall, growers no longer use older soybean varieties, which are generally dehiscent and less productive. They largely use new varieties obtained from the seed system or from a friend, but they do not renew them from year to year.

Concerning soybean haulm, the higher trend is observed in JENGUMA followed respectively by TGX1910-14F, TGX1910-10 F, TGX1830-20E and TGX1448-2D. JENGUMA variety producing more haulm, it offers a better possibility for ruminants and other herbivores feeding. It is followed by TGX1910-14F, TGX1910-10 F which are almost equal with respectively 1.47 t/ha and 1.44 t/ha. These two varieties having the best grain yields in the Center and North of Benin, they can be useful for both production of grains usable in poultry farming and human food on one hand and for production of haulm usable as feed for herbivores on the other hand. With haulm production almost comparable to that of these two varieties, TGX1830-20E could be added to this category of mixed soybean varieties if it had had a better potential.

Variation in grain and haulm yield of soybean varieties according to the agricultural development poles

The grain yields of the varieties TGX1910-14F, TGX1910-10F, TGX1448-2D, TGX1830-20E, and JENGUMA do not vary significantly between PDA 2, 3, and 4. Since the technical itineraries observed are the same in these PDA or production areas with high livestock potential, the differences in edaphic and climatic conditions are insignificant to significantly affect the grain yield of the five varieties. The five evaluated varieties are stable in the area for grain production. In a study of the determinants of soybean yield, Ollabodé *et al.* (2017) reported that lack of credit, the absence of subsidies for agricultural inputs, late onset of rains and the lack of government support for the sector are the factors that limit soybean production. In our study, rainfall do not influence soybean grain yields between PDA 2, 3 and 4 because the poles have similar climatic conditions favorable for soybean production. On the contrary, Ezin *et al.* (2025) reported yield differences for soybean accessions between the South (Commune of Abomey-Calavi) and the North (Bassila) of Benin where climatic conditions are really different.

On the other hand, the haulm production of soybean varieties TGX1830-20E and JENGUMA is similar for PDA 2 and 4 with higher values than those obtained in PDA 3. The conditions of PDA 2 and 4 are more favorable for haulm production for TGX1830-20E and JENGUMA.

This was also the case for TGX1910-14F, TGX1910-10F and TGX1448-2D but only in PDA 2 compared to PDA3. The grain yields of the varieties being similar between the three PDA, TGX1830-20E, JENGUMA, TGX1910-14F, TGX1910-10 F and TGX1448-2D give more haulm in PDA 2 while TGX1830-20E and JENGUMA give more haulm in both PDA 2 and 4. Thus, a farmer who produces one of the five varieties has a bonus of haulm to feed his animals in PDA 2 compared to PDA 3 and 4 while this haulm bonus is possible in both PDA 2 and 4 for TGX1830-20E and JENGUMA.

Furthermore, the grain yields of TGX1910-14F, which are 1.67 t/ha in PDA 2 and 1.59 t/ha in PDA 4, respectively, in the present study, are relatively higher than those of 0.75 to 1.2 t/ha in Badou (PDA 2) and 0.63 to 0.1 t/ha in Gbanlin and Ouénou (PDA4) reported by Bonou *et al.* (2025). As for haulm yields, the present study's yields are lower than those of Bonou *et al.* (2025). However, in their study, biomass was assessed before harvest, so in the fresh state.

Variation in grain and haulm yield of soybean varieties in Agricultural Development Poles 2, 3 and 4

In PDA 2, 3 and 4, grain yields of the TGX1910-14F variety are higher than those of the TGX1830-20E, JENGUMA and farmer varieties ($p<0.001$), which is similar. These differences are due to the genetic potential of the varieties and the level of suitability of biotic and abiotic conditions. With a cycle of 115 days and a potential yield of 2.5 t/ha, TGX1910-14F (MAEP, 2016) expressed its potential better than TGX1910-10F and TGX1830-20E which have a shorter cycle and a potential yield of 2.5 t/ha (MAEP, 2016; Adégbola *et al.*, 2017) in each of the PDA. Our results confirm the superior grain production performance of TGX1910-14F compared in particular to TGX1448-2D and the peasant variety in each area. Regarding biomass, the production of JENGUMA is higher than those of TGX1910-14F, TGX1910-10F, TGX1448-2D, TGX1830-20E and peasant variety, which were similar. Thus, despite its limited grain production in the present study, the JENGUMA variety provides more haulm for animal feeding. The profitability of soybean production of this variety can be improved by taking into account the surplus of haulm compared to the other varieties.

CONCLUSION

This study on the productivity of new soybean varieties in production areas with high livestock potentiality revealed that PDA 2 and 4 are more favorable for soybean haulm production. Within the three PDA (2, 3 et 4), TGX1910-14F is better for grain production followed by TGX1910-10F and TGX1448-2D while JENGUMA is better for haulm production. Determining the contribution of these varieties to animal feeding and their acceptability is important for the livestock sector.

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