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Viability of Soybean Seed Production Units in Benin

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Abstract:

This study focused on determining the viability (technical, economic, and overall) of soybean seed production units in Benin. Data were collected from a random sample of 155 seed production units using the PIB (Participatory Indicator-Based) approach and then analyzed using descriptive statistics and an ordered probit model. Although the technical (75.2) and economic (47.10) viability scores are mixed, the results reveal that only 2 out of 5 soybean seed farms are overall viable. Finally, the size of the workforce, the seed producer's membership in a cluster, and access to financing were the main determinants of the viability of soybean seed units in Benin.

Keywords: Viability, economic, technical, seed units, soybeans.

1- Introduction

1.1. Background

In 2020, as part of the process of aligning its seed policy with regional policies, Benin decided to professionalize its seed units by signing Interministerial Decree No. 2020-040/MAEP/MEF/DC/SGM/DAF/DPV/CJ/SA031SGG of July 17, 2020, aimed at promoting seed companies. This decree establishes the conditions for obtaining professional licenses for the production, importation, and distribution of plant seeds in the Republic of Benin. However, while this approach to promoting seed companies to ensure the availability, accessibility, and affordability of quality seeds is promising, very little is known about their viability. At the national level, the majority of studies on viability have focused on agricultural enterprises in general [1, 2, 3, 4]. The few recent studies on seed companies have been limited to assessing their financial profitability, the seed production and distribution system, and the challenges of reclaiming control of said system [5, 6].

Uncertainties therefore remain regarding the economic and technical viability of the promoted seed farms, particularly after the end of support from the government, donors, and projects, programs, and NGOs (non-governmental organizations).

This study helps to fill this knowledge gap regarding the viability of seed farms. It focuses specifically on soybean seed farms in Benin.

1.2. Research Objectives

The overall objective of this research is to determine the viability of soybean seed production units in Benin. Specifically, the study aims to:

- Describe Benin's soybean seed production units;
- Determine the technical, economic, and overall viability of Benin's seed production units;
- Identify the key determinants of the overall viability of seed production units.

1.3. Significance of the research problem

The adoption of high-quality seeds (germination capacity, moisture content, specific purity, varietal purity, vigor) is essential for increasing production and improving productivity [7] and, consequently, for reducing poverty. According to [8], the adoption of improved seeds stimulates not only the transition to high yields but also food security. Indeed, it has been proven that seed quality accounts for approximately 40% of the total variation in crop yields [9]. Furthermore, the productivity of other agricultural inputs depends heavily on the quality of the seeds used, in that not only is their direct contribution to total yield estimated at between 15% and 20% depending on the crop, but they also contribute to the efficiency of other inputs by up to 45% [10]. Moreover, the renewal of high-quality seeds from improved varieties not only helps to further increase yields but also reduces production costs due to their high germination rate thereby reducing the need for repeated sowing and because they are disease-free [11]. Seeds therefore undeniably play a decisive role in the development of all agricultural production [12].

However, in many developing countries, the current rate of seed renewal for improved varieties generally remains low. For example, [13] noted that in Cameroon, the corn seed renewal rate is approximately 5% per year. [14] estimated the adoption rate of certified rice seeds in Benin at 37% in 2016. Furthermore, the adoption rate for soybeans was 7.2% in 2023 [15]. Among the main reasons why seed renewal rates remain low is the inefficiency of the seed system, characterized by inadequate supply and high costs of quality seeds [16]. This constraint limits producers' access to quality seeds in sufficient quantities and at affordable prices. Since the timely availability of

sufficient quantities of quality seeds and their renewal at affordable costs depend fundamentally on the level of efficiency of the existing seed system [6] and thus on seed production units, improving the viability of these seed production units becomes a major strategic issue for ensuring the availability of soybeans.

1.4. Theoretical Framework

The concept of viability is often overused and confused with that of sustainability. [17] define viability as an entity's ability to survive. For authors such as [18], who focus on the economic aspect, viability is understood as the long-term viability of farms. These varied semantic approaches to the concept of viability have led to multiple methods for assessing it. Approaches to assessing the viability of agricultural farms are generally based on different types of performance. In the context of this study, these performance metrics incorporate the technical [19, 20] and economic [18, 21] aspects of these farms.

Regarding the viability of Beninese farms, [22] state that, with the exception of a few very specific production systems, agricultural entrepreneurs face significant difficulties in generating sufficient profits. [20] reinforce this by estimating that 49% and 22.4% of farms are economically and technically viable, respectively. According to [21], only 32% of Beninese farms are viable. Several factors influence the viability of farms. These factors can be classified into three main groups: the intrinsic characteristics of the farmer, factors specific to the farm, and factors external to the farm [23].

The elements of the first group are related, among other things, to the socioeconomic characteristics of the manager [24, 25], the producer's entrepreneurial orientation (innovativeness, proactivity, risk-taking) [26], and the operator's experience in the activity [27]. The characteristics specific to the enterprise constitute the factors in the second group and concern: the level of formalization of the farm, its internal organization, the labor force used (quantity and quality), the area under cultivation, and yield [28, 29]. Finally, factors external to the farm constitute the third group of parameters likely to influence the viability of agricultural operations. This group consists of indicators such as: contact with agricultural advisory services, membership in a Professional Agricultural Organization (PAO)/cluster, and access to agricultural financing [21, 30, 31].

2- Materials & Methods

2.1. Study Area

Soybeans, *Glycine max* (L.) Merr., are a legume cultivated in all of Benin's agricultural development zones (ADZs). A national survey identified 253 active soybean seed producers, spread across the entire country with the exception of ADZ 1. The study area for our research consists of ADAs 2, 3, and 4, which together account for 90.51% of Benin's soybean seed production units, representing 14.62%, 28.06%, and 47.83%, respectively.

2.2. Sampling and Data Collection

The number of seed farm operators to be surveyed was calculated using the following formula:

$$n = \frac{N}{1 + Ne^2} \quad (1) \quad [32] \quad \text{Where}$$

- n : is the sample size;
- N : is the size of the target population (all soybean seed producers in Benin), and
- e : is the precision level.

In this study, $N=253$ and $e = 5\%$, so $n =155$.

Second, the quota method was used to determine the number of seed producers to survey per municipality, while random sampling was used to select the units to survey within the municipalities. Based on the list of available seed units and the number of seed units to be surveyed in each municipality, the sampling scale was determined. It was applied iteratively until the list of seed units to be interviewed was established. The distribution of the surveyed seed units is as follows (**Fig 1**):

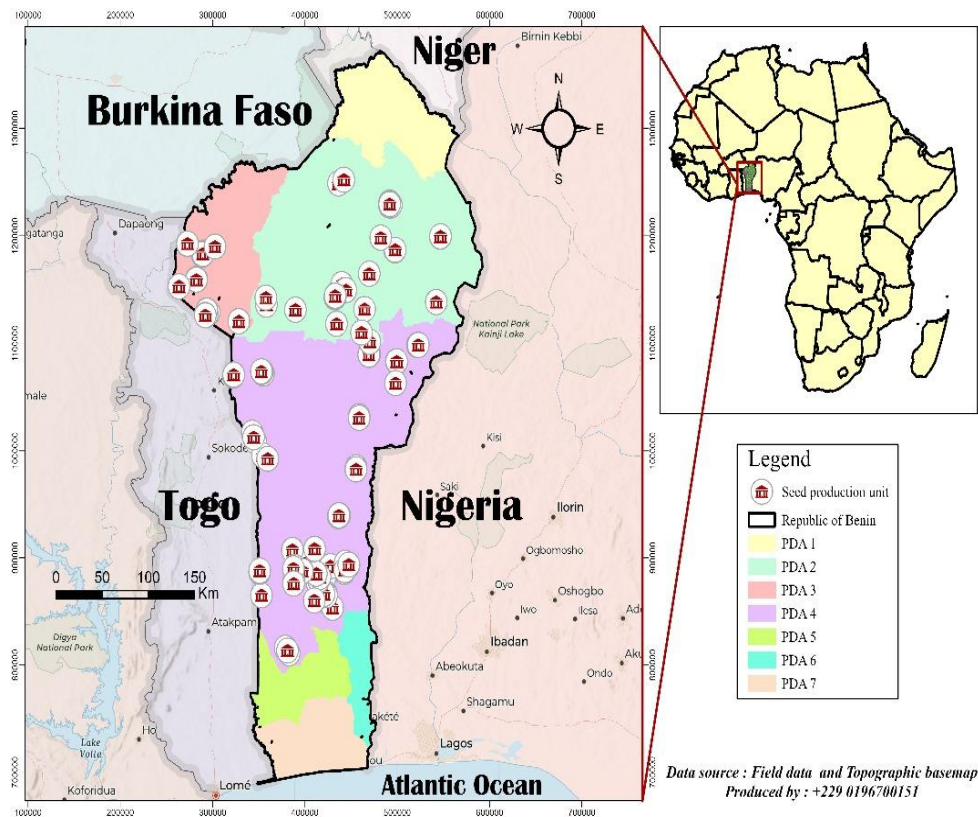


Fig. 1 Spatial distribution of the surveyed soybean seed producers.

Source: Author, 2025

2.3. Measuring the viability of seed farms

The methodology for estimating viability (technical and economic) adopted in this study is based on the PIB (Participatory Indicator-Based) approach [30, 33, 34, 35]. Four focus group discussions were organized with 38 seed unit operators (6 in Alibori and Atacora, 8 in Collines and Donga, and 10 in Borgou) to select indicators and weight them in a participatory manner with stakeholders. Two components were used to assess the viability of seed farms:

The technical component, which measures the effectiveness of agricultural practices in the seed units. The indicators considered are:

- The yield [30, 33, 36] ;
- Specific technical parameters related to seed production (degree or rate of infestation in plots, minimum distance from other fields, implementation of weed control measures) [37].

The economic component, which allows for the assessment of the financial health of seed production units. Its indicators are:

- Net income [20, 30, 33, 34] ;
- Available capital per hectare/wealth index/financial autonomy [33],
- Labor productivity [20].

Table 1: Description of viability indicators

No.	Indicators	Formula	Description	Comments	Feasible	Not viable
Technical Feasibility	Degree (rate) of infestation of plots	$T_{inf} = S_{inf} / S_{up}$	Infestation area / planted area	$\leq 0.2\%$: Viable	$\leq 0.2\%$	$> 0.2\%$
	Farm size or Cultivated area	-	Total area sown per seeding unit	> 2 ha: Viable	> 2 ha	≤ 2 ha
	Yield	$r = \text{Production Quantity} / \text{Area}$	Quantity of seed produced / Area	$\text{YIELD} > 1500$ = Viable	> 1500	≤ 1500
	Minimum distance from other fields	-	Minimum distance between the plot and other fields	> 10 meters: Viable	> 10 meters	≤ 10 meters
	Wastewater treatment	-	Number of purifications required to eliminate outliers	≥ 3 : Viable	≥ 3	< 3
Economic Viability	Net Margin (NM)	$NM = MB - CF$ $= PBV - CT$	Difference between gross revenue and total cost of production.	$NM \geq 0$: Viable	> 0	< 0
	Wealth Index (IR)	$IR = \text{Total Assets} / \text{Total Liabilities}$	Measures the company's ability to repay its debts using its assets.	$IR \geq 0$: Viable $IR < 0$: Not viable	> 0	< 0
	Financial Autonomy (AF)	$AF = \text{Equity} / \text{Total Liabilities}$	Assesses the company's dependence on external financing.	$AF \geq 50\%$: Viable; $AF < 50\%$: Not viable	$\geq 50\%$	$< 50\%$
	Labor Productivity (PML)	$PML = MN/MO$	Measures the efficiency of the workforce in production.	Sustainability is defined based on the 75th percentile.	$PML > 75\text{th percentile}$	$PML \leq 75\text{th percentile}$

Source: Author, 2025

Finally, the average scores for technical, economic, and overall viability of soybean seed production units were calculated. The formula used is:

$$SMc = \frac{1}{\alpha} \sum p \quad (2) \text{ Where}$$

- **SMc**: average viability score of soybean seed production units for component C;
- **p**: proportion of viable seed units for indicator j;
- **α**: number of indicators for component C.

The 50% threshold was adopted as a benchmark or minimum standard for assessing farm viability [38]. For this study, a seed unit is considered globally viable if and only if it is simultaneously technically and economically viable.

2.4. Determinants of the viability of soybean seed production units

Four classes were established for the viability of soybean seed production units (Table 2). The levels of the dependent variable are ranked on a scale (0 to 3). The scale corresponds to the different levels of overall viability of the seed unit. The dependent variable thus corresponds to an ordered variable [39]. Under these conditions, it is more appropriate to use an ordered probit model to identify the determinants of seed unit viability.

Table 2: Equivalences between weights and viability levels.

Average Viability Score	[0 ; 25[	[25 ; 50[	[50 ; 75[	[75 ; 100]
Viability Level	Not viable	Low viability	Moderately viable	Highly viable
Rank	0	1	2	3
Overall sustainability	No	No	Yes	Yes
Group	Group 1 (Not Viable)		Group 2 (Viable)	

❖ Specification of the model used

The overall sustainability level j is feasible only if the expected maximum utility (U_{ij}) derived from its adoption is greater than the utility (U_{ik}) derived from any other sustainability level, that is, when: $\delta = U_{ij} - U_{ik} > 0$ (3)

Let (δ) denote the expected profit. (δ) is an unobserved latent variable that depends exclusively on the alternative choices, socioeconomic, demographic, or institutional characteristics of the seed producer[40]. The difference in utility can be written as follows: $\delta = U_{ij} - U_{ik} = X_j\beta_j + \varepsilon_j - (X_k\beta_k + \varepsilon_k)$ (4)

And the estimated model is of the form: $\delta = \beta X_i + \varepsilon$ (5) [41]

(δ): is the unobservable latent variable associated with the acquisition of a level of viability;

X_i : constitutes the vector of explanatory variables;

β : the vector of parameters to be estimated;

i : seed unit and ε : the error term.

The empirical model is then as follows:

$$\delta = \beta_0 + \beta_1 \text{AGE} + \beta_2 \text{SEX} + \beta_3 \text{INSTRUCTION} + \beta_4 \text{CONTACT} \\ + \beta_5 \text{MAIN D'OEUVRE} + \beta_6 \text{CREDIT} + \beta_7 \text{CLUSTER} + \beta_8 \text{NRC}$$

Table 3: coding used.

No.	Variables	Code	Units	Type	Methods
1	Age of the sire	AGE	Year	Q	-
2	Sex of the seed producer	SEX	-	C	Male=1, Female=0
3	Educational level of the seed producer	EDUCATION	-	C	None, primary, secondary, university
4	Contact with agricultural extension services	CONTACT	-	C	Yes=1, No=0
5	Amount of labor used	LABOR	Man-days	Q	-
6	Access to credit	CREDIT	-	C	Yes=1, No=0
7	Cluster membership	CLUSTER	-	C	Yes=1, No=0
8	Number of capacity-building initiatives	NRC	Number	Q	-

Code: C = Qualitative variable; Q = Quantitative variable

Source: Author, 2025

3- Results

3.1. Technical viability of soybean seed production units in Benin

The average technical viability score for the soybean seed units surveyed is 75.2 (with $p < 0.01$) (**Table 4**). Analysis of this table shows that 91% of the seed units have an infestation level below the threshold of 0.2%. Regarding the indicator related to farm size, the results show that 79% of seed units planted areas greater than or equal to the prescribed standard (2 ha). Additionally, 75% of seed units achieved yields greater than or equal to 1.5 tons per hectare. As for compliance with the minimum distance between soybean seed farms and neighboring fields, 73% of seed units met this separation standard of more than 10 meters. Furthermore, only 58% of seed farmers perform at least three weedings during the soybean growing season. Finally, analysis of the table reveals that 73.55% of Benin's soybean seed production units are technically viable, while 26.45% are not.

Table 4: technical viability of seed units

Variable	Reference value	Observations	Proportion (%)	Standard deviation
Degree of infestation of plots	0.2%	155	91	0.29
Farm size or cultivated area	2 ha	155	79	0.41
Yield	1,500 kg/ha	155	75	0.22
Minimum distance from other fields	10 meters	155	73	0.45
Treatment	3	155	58	0.50
Average technical feasibility score	50	155	75.2	16.15
				Pr (T > t) = 0.0000
				Set
Not viable		02	1.29	26.45
Slightly viable		39	25.16	
Moderately viable		63	40.65	73.55
Highly viable		51	32.90	

Source: analysis results, 2025

3.2. Economic viability of soybean seed production units in Benin

The results show that only 38% of seed farms have positive net margins, and only 35% of them have a positive wealth index (**Table 5**). Furthermore, approximately 41% of seed production units have labor productivity above the norm. However, 74% of seed production units stand out positively due to their financial autonomy exceeding the norm.

Finally, the analysis of the table shows that the average economic viability score for Benin's soybean seed production units is 47.10, despite the fact that 63.87% of seed farms were economically viable, compared to 36.13% that were not.

Table 5: economic viability of seed units

Indicators	Reference value	Observations	Proportion (%)	Standard deviation
Net margin (NM)	0	155	38	0.49
Wealth Index	0	155	35	0.48
Financial independence	50%	155	74	0.44
Labor Productivity	75th percentile	155	41	0.49
Economic Viability Score	50	155	47.10	23.31
				Pr (T < t) = 0.0615
				Set
Not viable		8	5.16	36.13
Slightly viable		48	30.97	
Moderately viable		58	37.42	63.87
Highly viable		41	26.45	

Source: analysis results, 2025

3.3. Overall Viability of Benin's Soybean Seed Production Units

Figure 2 shows the radar chart of the average scores for the technical, economic, and overall viability of Benin's soybean seed production units. The radar chart indicates that the average overall viability score is 61.15 (>50), indicating that Benin's soybean seed production units are generally viable.

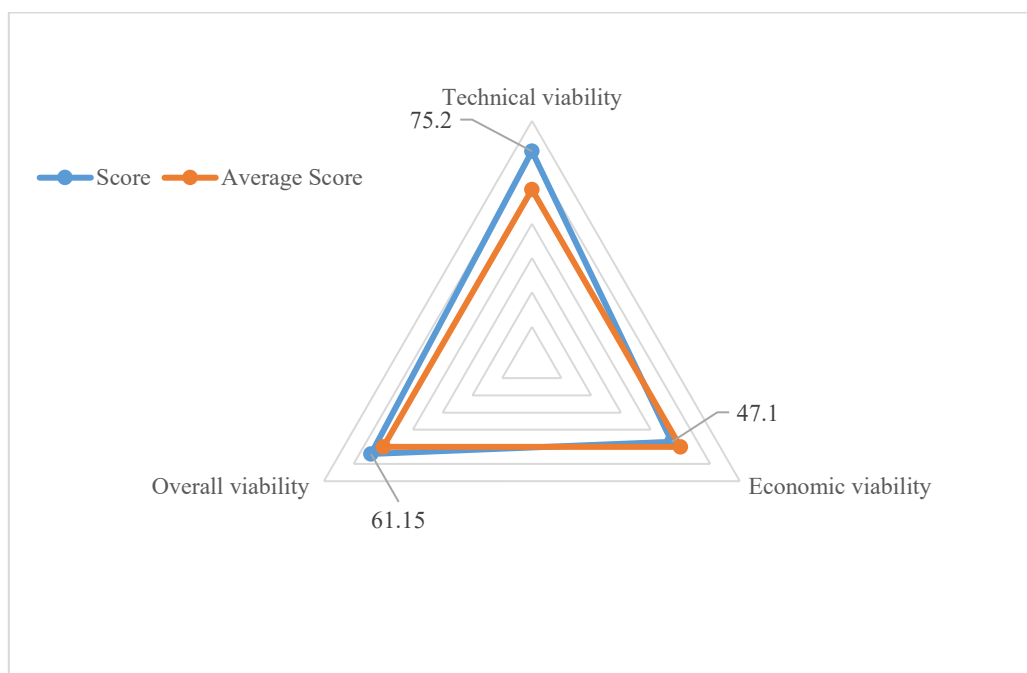


Fig. 2 Radar chart of average viability scores

Figure 3, meanwhile, shows the distribution of soybean seed production units according to the different components of viability. This figure indicates that 62.58% of soybean seed production units are not globally viable, compared to only 37.42% that are.

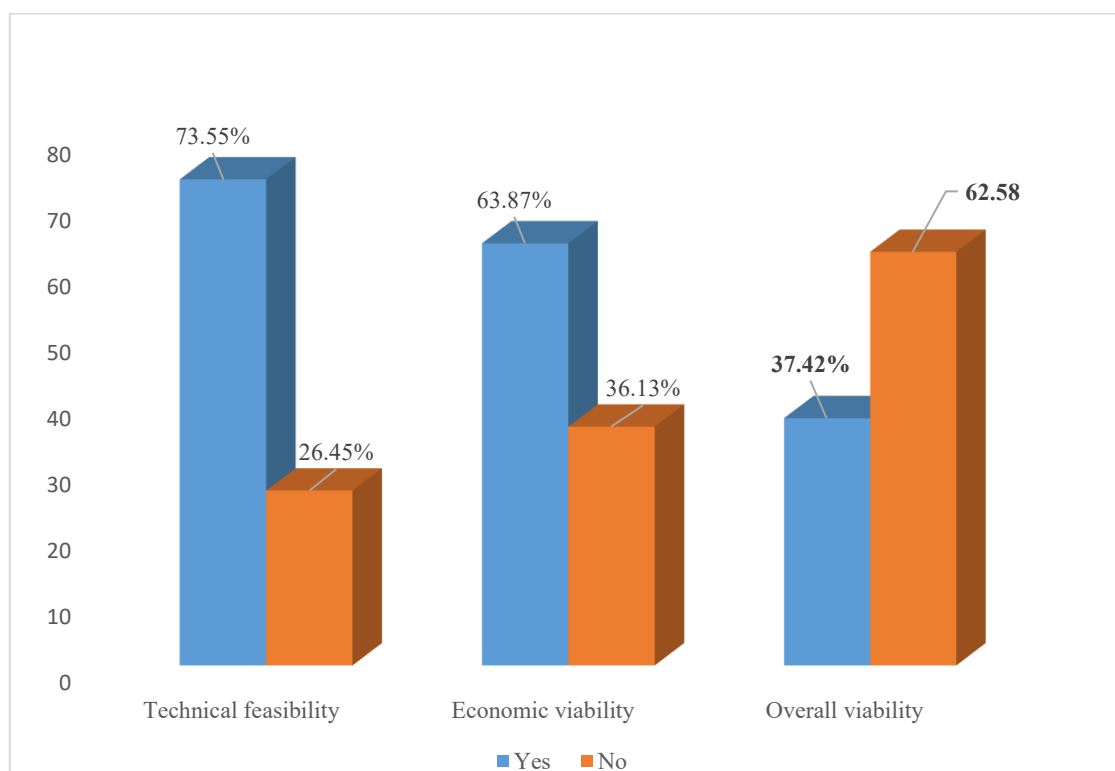


Fig. 3 Distribution of units by type of viability

3.4. Description of soybean seed production units in Benin

In most cases, soybean seed production farms in Benin are headed by men (92.26%), with an average age of around 41 (**Table 6**). Approximately 25.81% of seed producers have a primary school education, 41.29% a secondary school education, and 12.26%

a university education. However, the majority of them are literate (60.65%). On average, seed producers cultivate 11.33 hectares of soybeans. Soybean seed production units in Benin employ approximately four people, comprising both technical and administrative staff (operations manager, accountant, secretary, storekeeper) as well as laborers and day laborers. Most of these employees work without a formal written employment contract (83.23%).

From a relational standpoint, Beninese soybean seed producers generally maintain very good relations with both farmers and the government. The seed producers' relationship with the government is evidenced by their close contact with agricultural advisory services. In fact, 97.42% of the seed producers interviewed reported being in contact with these services. In the Beninese context, agricultural advisory structures for seed producers consist primarily of (i) the Territorial Agricultural Development Agency (ATDA), which handles monitoring, support, and advice, (ii) the Departmental Directorate of Agriculture, Livestock, and Fisheries (DDAEP), whose regulatory role is limited to oversight and enforcement, and (iii) the Directorate of Crop Production (DPV), which is responsible for seed certification. These agencies are all government-run. In addition to state agencies, technical and financial partners (TFPs) are also present in the field. In support of public agencies, TFPs organize operational training, capacity-building, and awareness-raising activities for stakeholders in the seed sector. Seed producers benefit from an average of three capacity-building sessions annually. The relational capacity of seed producers is strengthened by access to financing provided by the National Fund for Agricultural Development (FNDA) and the Microenterprise Development Support Project (PADME). Thus, just under half (43.87%) of Benin's soybean seed producers reported having received financial support from these two organizations.

As for the relationship between seed producers and farmers, it is strengthened by the establishment and facilitation of clusters, cluster initiatives, or PEA (agricultural business hubs). Clusters are established to facilitate and streamline business ties among the various actors in the seed chain, particularly between seed producers and farmers. However, it must be noted that only 15.48% of seed producers reported belonging to these various clusters.

Table 6: Characteristics of seed unit managers.

Variables	Not viable	Slightly viable	Moderately viable	Highly viable	Overall
Qualitative variables					
	Eff (%)	Eff (%)	Eff (%)	Eff (%)	Eff (%)
Gender					
Female	0 (0.00)	6 (3.87)	6 (3.87)	0 (0.00)	12 (7.74)
Male	2 (1.29)	46 (29.68)	82 (52.90)	13 (8.39)	143 (92.26)
Level of education					
None	0 (0.00)	9 (5.81)	21 (13.55)	2 (1.29)	32 (20.65)
Elementary	0 (0.00)	18 (11.61)	20 (12.90)	2 (1.29)	40 (25.81)
Secondary	1 (0.65)	21 (13.55)	35 (22.58)	7 (4.52)	64 (41.29)
College	1 (0.65)	4 (2.58)	12 (7.74)	2 (1.29)	19 (12.26)
Literacy					
No	1 (0.65)	21 (13.55)	36 (23.23)	3 (1.94)	61 (39.35)
Yes	1 (0.65)	31 (20.00)	52 (33.55)	10 (6.45)	94 (60.65)
Contact with agricultural advisory services					
No	0 (0.00)	2 (1.29)	2 (1.29)	0 (0.00)	4 (2.58)
Yes	2 (1.29)	50 (32.26)	86 (55.48)	13 (8.39)	151 (97.42)
Employment contract					

No	2 (1.29)	40 (25.81)	74 (47.74)	13 (8.39)	129 (83.23)
Yes	0 (0.00)	12 (7.75)	14 (9.04)	0 (0.00)	26 (16.77)
Access to credit					
No	0 (0.00)	23 (14.84)	53 (34.19)	11 (7.10)	87 (56.13)
Yes	2 (1.29)	29 (18.71)	35 (22.58)	2 (1.29)	68 (43.87)
Membership in a seed producer organization					
No	0 (0.00)	7 (4.52)	13 (8.39)	3 (1.94)	23 (14.84)
Yes	2 (1.29)	45 (29.03)	75 (48.39)	10 (6.45)	132 (85.16)
Membership in a seed cluster					
No	2 (1.29)	49 (31.61)	69 (44.52)	11 (7.10)	131 (84.52)
Yes	0 (0.00)	3 (1.94)	19 (12.26)	2 (1.29)	24 (15.48)
Quantitative variables					
	Mean ± Standard Deviation	Mean ± Standard deviation	Mean ± Standard deviation	Mean ± Standard deviation	Mean ± Standard deviation
Age of the sire (years)	53 ± 4.24	38.83 ± 18.39	42.77 ± 17.54	44.31 ± 9.05	41.71 ± 17.26
Seed workforce (number)	3.50 ± 2.12	2.67 ± 4.02	3.55 ± 6.59	6.69 ± 11.05	3.52 ± 6.37
Area under production (ha)	3.50 ± 2.12	12.90 ± 43.09	10.05 ± 23.74	14.92 ± 18.57	11.33 ± 31.04
Number of capacity-building activities	3.50 ± 3.54	3.21 ± 1.89	2.85 ± 1.08	2.92 ± 0.49	2.99 ± 1.40

Note: The values in parentheses represent **percentages (%)**

Source: *Analysis results, 2025*

3.5. Determinants of the viability of soybean seed production units in Benin.

The ordered probit model estimated for the analysis of determinants of the overall viability of seed companies is globally significant ($p=0.005$) (**Table 7**).

The socioeconomic characteristics of the seed producer namely age, gender, and educational level had no significant influence on the overall viability of the operation. In contrast, the amount of labor used significantly and positively affects the level of viability of soybean seed production units at the 5% statistical significance level ($\beta = 0.033$; $p = 0.032$). The seed producer's membership in a cluster was also found to be a highly significant factor affecting the overall viability of seed production units ($\beta = 0.450$; $p = 0.09$). Finally, the seed producer's access to agricultural financing had a notable negative effect on farm viability at the 1% statistical threshold ($\beta = -0.663$; $p = 0.001$).

Table 7: Results of the ordered probit model.

Variables	Coefficient	Std. Error	z	p-value	Marginal effect (Not significant)	Marginal effect (Weakly significant)	Marginal effect (Moderately viable)	Marginal effect (Highly viable)
Characteristics of the seed source								
Age of the seed source	0.005	0.006	0.880	0.379	-0.000	-0.001	0.001	0.001
Gender of seed producer (Male=1)	0.447	0.367	1.220	0.223	-0.014	-0.135	0.087	0.062
Level of education (ref: None)								
Elementary	-0.375	0.284	-1.320	0.186	0.011	0.114	-0.072	-0.053
Secondary	-0.216	0.258	-0.840	0.402	0.005	0.064	-0.036	-0.033
College	-0.136	0.341	-0.400	0.690	0.003	0.040	-0.021	-0.022
Institutional and productive characteristics								
Contact with agricultural advisory services	0.506	0.600	0.840	0.398	-0.016	-0.153	0.098	0.070
Amount of labor used	0.033**	0.015	2.140	0.032	-0.001	-0.010**	0.006**	0.005**
Seed cluster membership	0.450*	0.273	1.650	0.099	-0.014	-0.136*	0.087*	0.063*
Access to credit	-0.663***	0.196	-3.390	0.001	0.020	0.201***	-0.129***	-0.092***
Number of capacity-building initiatives	-0.078	0.069	-1.130	0.260	0.002	0.024	-0.015	-0.011
Model Summary								
	Cut 1				-1.885			
	Cut 2				0.137			
	Cut 3				2.100			
	Prob > χ^2				0.005			
	Log-likelihood				-135.052			
	Pseudo-R ²				0.085			
	LR χ^2 (10)				24,960			
	Number of observations				155			

*** p < 0.01; ** p < 0.05; * p < 0.10

Source: analysis results, 2025

4- Discussions

4.1. Technical viability of soybean seed production units in Benin

The average technical viability score for Benin's soybean seed production units is 75.2 ($75.2 > 50$ with $p < 0.01$). These values reflect an overall acceptable and statistically significant level of technical viability at the 1% significance level for Benin's soybean seed production units. They thus indicate that Benin's seed production units are generally technically viable. The observed level of technical viability depends on seed producer's good understanding of technical viability indicators. Indeed, a detailed analysis of the technical viability indicators reveals notable strengths. The controlled infestation rate (91% of units below the 0.2% threshold) is attributable to the adoption of good agricultural practices and rigorous phytosanitary monitoring of seed production plots. This rate indicates that approximately 91% of units produce healthy soybean seeds. Indeed, proactive soil and pest management combined with the use of resistant varieties of foundation seeds can significantly reduce health risks on farms [42]. Furthermore, the 9% of non-compliant units may suffer from a lack of access to inputs (quality basic seeds, plant protection products, fertilizers) and/or limited mastery or knowledge of techniques to better control pest attacks and the spread of soybean diseases.

Furthermore, analysis of the farm size indicator shows that 79% of seed production units planted areas of 2 hectares or more, thereby meeting the prescribed standard in this regard. However, the relatively moderate rate of compliance with the yield standard ($75\% > 1.5 \text{ t/ha}$) is at a critical threshold. [43] identify several causes of yield discrepancies: poor-quality seeds, outdated farming practices, and limited access to inputs. Lack of plot maintenance (weeding, hilling), farming practices (poor crop rotation, no fallow), or a lack of specific inputs (fertilizer, inoculum) may contribute to this result. This finding can also be explained by the realities of the production environment, which has been shaped by the climatic variability observed in recent years a factor influencing national crop productivity [44].

As for compliance with the minimum distance between soybean seed farms and neighboring plots, 73% of farms met the separation standard set at more than 10 meters. This finding indicates that seed producers are aware of the risks of contamination and variety mixing. [45] notes that spatial isolation is critical for preserving the genetic purity of seeds. The 27% non-compliant cases could reflect land constraints or bad faith (more often on the part of local residents than seed producers).

Finally, 58% of seed producers perform at least three cleaning operations during the soybean seed production season. Cleaning is a crucial step in obtaining high-quality seeds. [46] explains that mechanical or manual cleaning removes impurities and defective seeds, ensuring compliance with standards. The low rate observed for the cleaning operation could be explained by the high rate (91%) of healthy plots combined with compliance with the minimum distance from other fields (73%). The combination of these two measures greatly limits the impact on the varietal purity of seed production plots that adhere to them. Consequently, very few off-types are observed in these plots. This low rate could also be explained by the labor-intensive nature of the activity, which is performed manually, as post-harvest operations are often carried out using rudimentary equipment [5]. All in all, the technical viability of the seed farms studied (75.2) is good but could be improved. Indeed, according to

[42], optimizing farming practices (crop rotation, integrated pest management, etc.) could improve this score by reducing technical losses.

However, our results differ from those of [47] and [20], which reported low technical viability scores of 50 and 22.4, respectively, for Beninese farms. These low rates can be explained by the fact that these two authors focused their research on Beninese livestock farms; given that these farms are in most cases characterized by poor zootechnical parameters (high morbidity and mortality rates, low Average Daily Gain, low prolificacy, etc.).

4.2. Economic viability of Benin's soybean seed production units.

The average economic viability score for Benin's soybean seed production units is 47.10 (<50), implying that Benin's soybean seed production units are not economically viable. The proximity of this score to the reference threshold (50) indicates a trend toward viability that could be realized by implementing targeted interventions. Furthermore, the p-value ($p=0.0615$) reveals that the economic viability of the seed units is statistically insignificant at the 5% threshold. This reflects some uncertainty regarding the stability of these units' economic viability, which offers a glimmer of hope for reaching the benchmark score. This glimmer of encouragement is reinforced by the fact that approximately two-thirds of the units are found to be economically viable. The low economic viability score of soybean seed units in Benin is explained by:

(i) The relatively low net margins of the seed units. The results reveal that only 38% of soybean seed farms show positive net margins and are therefore financially profitable. This low rate reflects the profitability challenges faced by soybean seed production units. These challenges are linked to the high production costs (basic seeds, materials and equipment, fertilizers) of certified seeds and/or insufficient selling prices [48].

(ii) The low proportion of soybean seed farms with a positive wealth index. In fact, only 35% of farms have reached the minimum wealth index level, indicating that very few seed producers are able to repay their debts with their assets. This rate suggests that the majority of units do not accumulate sufficient capital to invest or withstand shocks. These units neither raise capital nor make significant investments (machinery & equipment).

(iii) Suboptimal use of labor. In fact, only 41% of seed production units have labor productivity at or above the standard (> 75th percentile). This low proportion of seed production farms indicates underutilization of labor among soybean seed production units. This indicator also points to a lack of training, planning, and, above all, optimal distribution of workloads, which consequently proves inefficient.

Furthermore, the results showed that 74% of the seed units studied are financially self-sufficient. These results are consistent with those of [34], which demonstrated that farms are financially self-sufficient. This high proportion of financially self-sufficient seed units suggests that the majority of units operate without undue reliance on external financing. This self-sufficiency therefore reduces the risks of dependence on external factors.

In summary, our findings are consistent with those of [35] which revealed that despite the low average economic viability score, most farms in Benin were economically viable, with 78.16% of farms meeting this criterion. Our results also align with those of [3] which found that 86% of farms were economically viable. However, our results differ from those of [34] which showed that farms in Benin had a level of economic viability above the 50 threshold. They also contradict the findings of [20] which indicated that only 48.98% of Beninese farms were economically viable.

4.3. Overall Viability of Soybean Seed Production Units in Benin

The results showed that only 37.42% of seed production units are viable. This result is explained by the low average economic viability score of the majority of the seed production units studied. Indeed, the scores for nearly all indicators of the economic viability of seed production units are low (net margin 38%, wealth index 35%, and labor productivity 41%). Furthermore, 21% of seed production units cultivate areas of less than 2 hectares. However, [49] have shown that small farms struggle to achieve economies of scale, thereby limiting their profitability. We note that 25% of seed farms achieve yields below 1.5 t/ha. This low yield, combined with high production costs, further traps seed producers in the decline of their operations' viability. In this context, increasing the area under cultivation, coupled with reducing production costs, mechanizing operations, and optimizing labor, will enable viable seed operations to flourish. These measures, complemented by the availability of seeds at profitable prices, offer alternatives for improving the overall viability of seed operations.

Our findings are consistent with those of [21], which concluded that very few agricultural enterprises are profitable in a context where only 32% have been able to reach their break-even points. Our results also align with those of [3] which showed that only 26% of agricultural enterprises are viable. Finally, [20] concluded, based on, that only 16.3% of farms were both technically and economically viable. Considerable efforts therefore remain to be made to ensure the viability of Benin's soybean seed production units.

4.4. Determinants of the viability of Benin's soybean seed production units

The amount of labor used has a significant and positive effect on the viability of soybean seed production units at the 5% statistical significance level ($\beta = 0.033$; $p = 0.032$). It was found that viable Beninese soybean seed production units employ a significantly larger workforce than non-viable units, even though the latter cultivate larger areas. Under these conditions, the workload of workers in viable units is therefore lower than that of workers in non-viable units. This more balanced distribution of labor intensity among workers in viable units consequently leads to better monitoring of soybean production operations on these farms. At the end of the growing season, due to the more rigorous and detailed monitoring of plots employing more laborers, these plots consequently yield good harvests. All of this undoubtedly leads to higher income from the sale of soybean seeds and, consequently, greater viability. Our results are consistent with those of [50] and [3] which demonstrated the positive influence of labor on the viability of agricultural operations. Furthermore, [51] indicates that although a large workforce places greater demands on farm cash flow, it provides a definite return on investment and thereby ensures farm viability. Additionally, [52] confirms that effective labor utilization is one of the key factors in ensuring the viability of agricultural operations.

Although the age of the seed producer did not appear to influence the overall viability of the seed production units surveyed, the results nevertheless revealed that the oldest seed producers are those with the most viable operations. Furthermore, it was found that the level of viability of seed production units in the study area increases with the age of the seed producer. This result is very interesting because it highlights the importance of capitalizing on the experience accumulated in seed production by the unit operators, which in turn makes the farms more viable. In this vein, [3] identified the entrepreneur's experience and motivation as factors that positively influence viability. Similarly, [53] also demonstrates that farmer's lack of knowledge and experience undermines the viability of their farms.

The results showed that a seed producer's membership in the cluster significantly improves the overall viability of its operation. Indeed, this network enables the creation and, above all, the maintenance of strong business ties among its members. It also serves as a mark of trust and a guarantee for MFIs (microfinance institutions) when granting loans to seed producers; all these factors contribute to the sustainability of the units. Our results are consistent with those of [31] and [27] which found that an agricultural actor's membership in a cluster enables them to access agricultural productivity services, thereby ensuring the sustainability of their operations. There are thus very positive externalities from the cluster that improve the economic, social, and institutional environment for the actors [54].

Finally, access to agricultural credit by seed producers has been a negative factor in ensuring the viability of their operations. Our results differ from those of [55] and [56] who argue that factors related to access to financing contribute to the viability of farms. Our results also contradict those of [57] which emphasizes that loans granted by MFIs are essential investments for agricultural production activities and help ensure their viability. Furthermore, our findings align with those of [58], which explains that the absence of a well-coordinated institutional and organizational structure for credit administration has sometimes led to unforeseen negative consequences. This situation, combined with financing/loans ill-suited to agricultural activities, further impoverishes seed producers and makes their farms less viable [59, 60].

5- Conclusion

This study, which focused on the viability of soybean seed production units, has contributed to a better understanding of their technical and economic performance. As a result, 2 out of 5 soybean seed farms were found to be viable both technically and economically. In reality, very few seed producers met economic standards, which had a negative impact on overall viability. Since technical and economic factors are essential to achieving the overall viability of seed production units, actions (reducing production costs, improving seed sale prices, increasing labor productivity, promoting clusters, and providing financial education for the proper use of agricultural loans) must therefore be prioritized to improve the viability of soybean seed production units.

Abbreviations:

ATDA: Territorial Agricultural Development Agency

ADZ: Agricultural Development Zones

CF: Fixed Cost

TC: Total Cost

DDAEP: Departmental Directorate of Agriculture, Livestock, and Fisheries

DPV: Directorate of Crop Production

FA: Financial Autonomy

FNDA: National Fund for Agricultural Development

IR: Wealth Index

GM: Gross Margin

MN: Net Margin

NGO: Non-Governmental Organization

PADME: Microenterprise Development Support Project

PAO: Professional Agricultural Organization

GVP: Gross Value Product

PEA: Agricultural Enterprise Hub

PIB: Participatory Indicator-Based

PML: Labor Productivity

SMc: Average Score

TFP: Technical and Financial Partners

Supplementary material: Nothing

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Data Availability Statement

The data supporting the findings of this study can be found at: <https://bit.ly/4v0vdow>

Conflicts of Interest

The authors declare no conflicts of interest.

Necessary registration details: not applicable.

Ethics Statement: The research was conducted through a survey of soybean seed producers in Benin. It complied with personal data protection standards and adhered to the

Declaration of Helsinki. The protocol was approved by the Ethics and Standards Committee of the National Federation of Seed Producers of Benin (FNPS-Benin), and the research was carried out in accordance with their guidelines. The approval document reference number is: No..096/2024/FNPS-B/PCA/COORD/SC

Consent to Participate: The surveyed seed producers provided their informed consent to participate in the study.

Consent to Publish declarations: The surveyed seed producers consented to the publication of information resulting from this study under the Creative Commons license.

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