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Determinants of farmers' adoption of *Parkia biglobosa* (Jacq.) R.Br. ex G. Don.pods for weed management (Burkina Faso)

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Abstract: In Burkina Faso, the use of biological methods for weed control remains relatively limited and poorly adopted, largely due to a range of socio-demographic and economic barriers. This study aims to identify the determinants that constrain the adoption of *Parkia biglobosa* pods option for the sustainable management of agricultural weeds. A random sampling approach was employed to survey 262 farmers, comprising 127 adopters of *Parkia biglobosa* pods in weed management and 135 non-adopters. The questionnaire and interview guides were used to collect data. The results of the Logit model estimation indicate that training in biological weed control, membership in an association, age, farm size, land tenure, and education level significantly influence the adoption of *Parkia biglobosa* pods in agricultural weed management. These results may help guide policymakers and farmers' organizations engaged in the promotion of biological control practices. Accordingly, strengthening farmers' training on biological methods for managing agricultural pests, together with the implementation of sound land tenure policies, could foster a wider adoption of *Parkia biglobosa* pods in sustainable weed management.

Keywords: biological control, weed, pod, agroecosystem, Logit model.

Introduction

The agricultural sector is the most important in terms of employment in Burkina Faso, serving as the main source of income for rural populations. Its development is crucial for achieving food security. Agricultural production is primarily dominated by cereal crops like millet, sorghum, maize, and rice. These cereals constitute the country's main staple crops and are essential for food security (Sankara *et al.,* 2017). However, their development is heavily affected by climatic hazards, soil infertility, and weeds. These factors can cause significant damage and compromise food security. Climatic hazards, such as floods, droughts, and irregular rainfall, disrupt cereal production, perpetuating food insecurity among vulnerable populations (Pyšek and Richardson, 2010). Soil poverty is partly linked to the collection of crop residues at the end of the harvest for other purposes. This use impoverishes the soil and further degrades it. The pressure from weeds is explained by their growth potential and their high adaptability within agroecosystems (Doré *et al.,* 2004). Thus, in southwestern Burkina Faso, *Crotalaria barkae* Schweinf., *Pupalia lappacea* (L.) Juss., *Senna occidentalis* (L.) Link, *Ipomoea eriocarpa* R. Br., *Triumfetta cordifolia* A. Rich., *Striga hermonthica* (Del) Benth., and *Indigofera spicata* Forssk. are among the weeds whose management remains a major concern for farmers (Sourabié *et al.*, 2024). These weeds compete with crops for resources such as water, light, and mineral nutrients, thereby reducing yields and lowering harvest quality. The main method of controlling these weeds is the widespread and uncontrolled use of synthetic chemical herbicides. Although this method is effective in controlling weed growth, it poses several problems : the development of resistance in weeds, environmental impacts (water pollution, toxicity to fauna and flora), and risks to human health (Zoundji *et al.,* 2018). For these ecological and health reasons, it is now necessary to develop alternative weed control methods based on the use of plant resources (Kobayashi, 2004). Traditional knowledge regarding the use of local plants in agriculture remains a promising avenue to explore. Several studies have already demonstrated the use of plant organs in managing weeds in cereal and vegetable crops. Moreover, effective treatments based on plant extracts have even been developed for cereal and vegetable crops (Ahmad *et al.,* 2008). In Burkina Faso, most studies have focused on the use of plants by local communities for medicinal, nutritional, and construction purposes (Olivier *et al.,* 2012). In southwestern of Burkina Faso, research by Kambou *et al.* (2000) and Sourabié *et al.* (2020) reports that some farmers use *P. biglobosa* pods to limit the spread of weeds, mainly *Striga hermonthica*. This sustainable weed control practice, as well as beneficial, is difficult to maintain. In addition, it is less adopted by farmers due to a number of socio-demographic and economic barriers that limit their choice.

The present study aims to identify the determinants that constitute constraints to the adoption of *P. biglobosa* pods for sustainable agricultural weed management.

Results

Demographic characteristics of respondents

The results presented in Table 1 show that the average age of adopters is lower than that of non-adopters (51 years versus 64 years), with a statistically significant difference at the 1% level. Table 2 shows that 127 respondents (48.5%) adopt *P. biglobosa* pods for controlling *Striga hermonthica*, while 135 respondents (51.5%) do not. In terms of gender, the results show a predominance of male farm managers (97.6%) who adopt the practice compared to female farm managers (2.4%). Information on the marital status of respondents indicates that 74% of adopters were in a relationship (married or living with someone). Among non-adopters, this percentage is 84.7%. In contrast, only 16.5% of adopters reported being single.

Socio-economic characteristics of respondents

Table 3 shows that the majority of respondents practice Islam : 52.8% among adopters versus 60.7% among non-adopters. Other religions practiced include Animism and Christianity. The educational level of adopters of *P. biglobosa* pods is relatively low, with 25.3% having completed primary, post-primary, or higher education. Among non-adopters, 78.8% are illiterate, although some are able to speak French. Approximately 13.4% of adopters have received training in pest and weed management from agricultural development services. Regarding membership in farmers' organizations, 29.9% of adopters are members, compared to 20.7% of non-adopters. Agriculture is the primary activity for 94.4% of respondents who adopt *P. biglobosa* pods, whereas only 45.2% of non-adopters report agriculture as their main activity.

Analysis of the determinants of adoption

Table 4 summarizes the results of the Logit model estimation. According to the analysis, only the variables related to training in biological control, membership in farmers' organizations, age, farm size, land tenure, and education level were found to be significant. The first three factors, namely training received in biological control techniques, membership of an association, and level of education, have a positive and significant influence on the decision to adopt at the 1% level. Age, farm size, and land tenure also significantly influence adoption at the 5% level. In contrast, variables such as gender, level of study, religion, perceptions of *Striga hermonthica* control, and land tenure ($p > 0.05$) are not determinants in the adoption of *P. biglobosa* pods.

Respondents' perceptions of the benefits of adopting Parkia biglobosa pods

The reasons given by respondents regarding the benefits of *P. biglobosa* pods are diverse (Table 5). The main advantages can be summarized as follows: improved agricultural yields (53.0%), increased nutrient availability (19.5%), and soil fertilization (16.8%). The frequencies of citation for other benefits remain low (<10%).

Respondents' perceptions of the constraints related to non-adoption of Parkia biglobosa pods

Several constraints (Table 6) hinder the use of *P. biglobosa* pods in agricultural systems. The main difficulties, in order of importance, are an increased workload (58.2%), followed by the unavailability of pods at certains times of the year (48.3%), lack of agricultural equipment (36.2%), and the difficulty of transporting the pods to the fields (23.0%).

Methods of use of Parkia biglobosa pods by adopters

The ways in which *P. biglobosa* pods are used in agricultural systems are presented in Figure 1. Burying (52.8%) is the main method of use. Two types of Burying methods (Figure 2) were identified: mounding Burying (36.7%) and flat plow Burying (41.6%). Spreading the pods on the field was reported by 20.4% of respondents, while processing the pods into powder was mentioned by 8.0% of respondents.

Discussion

Education level

The adoption of *P. biglobosa* pods as a means of controlling weeds varies according to the farmer's level of education. It is high among uneducated respondents and low among those with a higher education level. These results confirm those obtained by Smith *et al.* (2001) on the factors limiting the adoption of agroecological practices by market gardeners in Leguema, Kuinima, and Kua in Burkina Faso. Indeed, they report that formal education positively influences decisions to adopt biological practices. However, a study by Böcker et al. (2019) indicated that education could also constitute a constraint in the adoption of innovations and in technology transfer aimed at increasing agricultural production. Many authors have also reported similar findings, showing that the level of education is a key determinant in the adoption of technologies (Teklehaymanot *et al.,* 2002 ; Puig *et al*., 2018 ; Amichi *et al.,* 2016).

The age of the farm manager

The age of the farm manager influences the adoption of *P. biglobosa* pods in agricultural systems. Older farmers are less likely to adopt this biological control practice than younger farmers, are more favorable to its adoption. Young farmers are more curious, willing to take risks, and therefore more receptive to new innovations (Van den Berg, 2013). They also adapt more readily to the requirements of a biological production system, which demands physical effort for weed management. This result corroborates the conclusions of Venkatesh (2003), who noted that the effort required to use a technology affects its adoption. The limited availability of agricultural labor may thus constitute a constraint for the adoption of *P. biglobosa* pods in agroecosystems. For this reason, farmers managing large farm areas may find it difficult to adopt *P. biglobosa* pods as a method of weed management. The size of the farm significantly influences the adoption of weed management practices.

Training

Participation in training on alternative methods of controlling agricultural weeds is a factor that positively influences the choice of *P. biglobosa* pods. Trained farmers have information about the advantages and are therefore more favorable to the option of biological control of agricultural pests. They are more likely to adopt this innovation, which increases the adoption rate of new agricultural technologies (Barungi *et al.,* 2013). Our results are consistent with those of Mwangi and Kariuki (2015), who showed that membership in a farmers' association positively influences the choice of new agricultural technologies.

Table 1. Average age of respondents.

Variable	Adopters	Non-adopters	P-value
	Average	Average	
Age	51±21.7	64±18.5	.000***

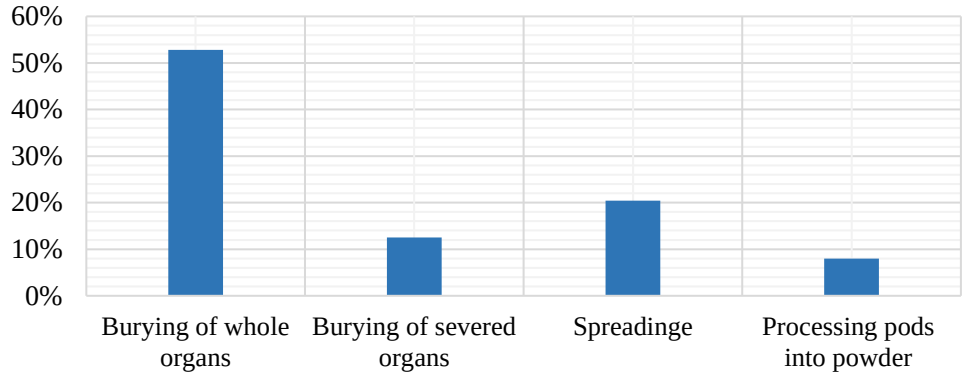

Figure 1. Modes of use of *Parkia biglobosa* pods in agroecosystems

Table 2. Demographic characteristics of respondents.

Variables		Adopters (n=127)		Non-adopters (n=135)	
		Number	%	Number	%
Gender	Man	124	97.6	129	95.6
	Women	3	02.4	6	04.4
Origin	Native	78	61.4	101	74.8
	Non-resident	49	38.5	34	25.2
Marital status	Married	94	74.0	113	84.7
	Bachelor	21	16.5	14	10.4
	Widower / Widow	12	09.4	8	05.9

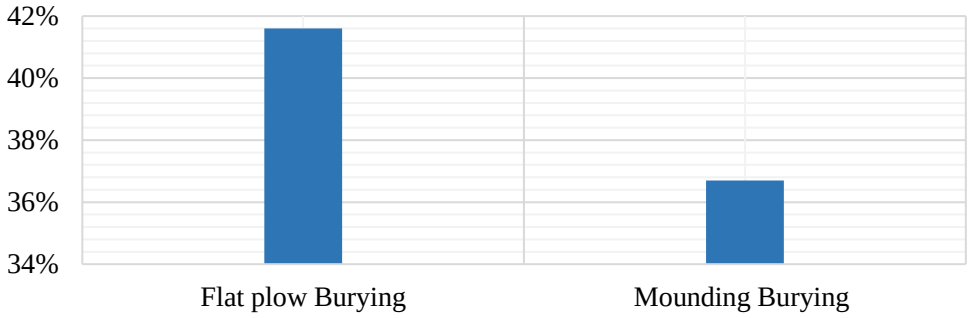

Figure 2. Types of burying of *Parkia biglobosa* pods in agroecosystems

Table 3. Socio-economic characteristics of respondents.

Variables		Adopters (n=127)		Non-dopters (n=135)	
		Number	%	Number	%
Educational level	No formal education	95	74.8	101	78.8
	Primary education	19	15.0	15	11.1
	Post-primary education	11	08.7	19	14.1
	Higher education	2	01.6	-	-
Religion	Islam	67	52.8	82	60.7
	Christianity	31	24.4	34	25.2
	Animism	29	22.8	19	14.1
Main activities	Farmer	120	94.4	61	45.2
	Breeder	6	04.7	39	28.8
	Trader	01	0.7	35	25.9
Membership in an association		38	29.9	28	20.7
Training		17	13.4	39	28.9

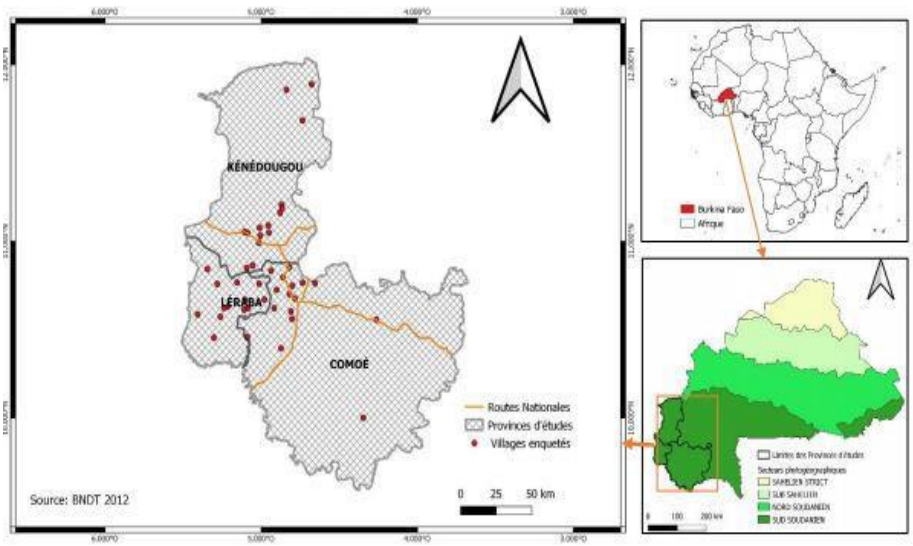

Figure 3. Location of the study area.

Table 4. Determinants analysis of *Parkia biglobosa* pods adoptation.

Variables	Coefficient	P-Value	Erreur St.
Gender	-3.017	0.082	0.123
Age	2.130**	0.004	0.175
Education level	0.712***	0.000	0.010
Farm size	0.214**	0.003	0.201
Land tenure	4.063	0.003	0.181
Religion	-0.630	0.311	0.305
Training	2.09***	<.0001	0.023
Membership in an association	1.86***	<.0001	0.090
Perception of weed control	5.170	0.615	0.321
Logistic regression			
Number of obs = 262			
Prob > chi2 = 0.000			
Pseudo R2 = 1.004			

(***) = Significant at 1% ; (**) = Significant at 5%.

Table 5. Benefits of using *Parkia biglobosa* pods.

Advantages	Citation frequency (%)
Improvement of production	53.0
Increased nutrient content	19.1
Crop resilience	5.4
Limiting soil erosion	8.1
Improvement of soil structure	5.0
Soil fertilization	16.8
Promotes soil organism activity	2.8
Loosens soil	3.4

Table 6. Constraints related to the non-adoption of *Parkia biglobosa* pods.

Constraints	Citation frequency (%)
Difficult to transport to the fields	23.0
Lack of awareness and promotion	9.5
Inappropriate uses	1.6
Long decomposition periods	6.5
Unavailable	48.3
Land tenure insecurity	7.3
Low efficacy	9.6
Difficult to process	3.0
Poverty	7.8
Increased workload	58.2
Lack of labor	9.8
Lack of agricultural equipment	36.2

Membership in an association

Most agroecological practices are promoted through farmers' associations. The results indicate that membership in such an association positively influences the adoption of *P. biglobosa* pods in agricultural systems. However, the majority of respondents are not members of these organizations, which may explain the low adoption rate of *P. biglobosa* pods. For this reason, Puig *et al.* (2018) in the Democratic Republic of Congo highlighted the link between the adoption of agroecological practices and membership in farmers' associations. Membership of an association provides many advantages in terms of training, awareness-raising, guidance on agroecology, access to technical advice, credit, equipment, subsidies, and donations. This would facilitate the choice of biofertilizers, biopesticides, and bioherbicides for production and use (Doré *et al.,* 2004). Similarly, Böcker *et al.* (2019) report that being member of an association has a positive influence on the adoption of sustainable production systems. Indeed, membership in an association allows producers to learn about the likely benefits of these practices.

Land tenure

Land tenure is an important variable which determines the adoption of *P. biglobosa* pods for weed control. The results reveal that farmers need secure land to adopt biological control practices. This observation was also made by Smith *et al.* (2001), who noted that farmers without secure land are constantly under the threat of having their plots withdrawn. Secure land allows farmers to undertake agroecological investments without fear. The presence of a land title secures the farmer's investments and enables the implementation of desired agroecological practices. Furthermore, considering that *P. biglobosa* pods contribute to soil fertilization, land insecurity may create the perception that the farmer is investing for the landowner, who could at any time take back the cultivated plot. This observation was also made by Diaby *et al.* (2020), who identified land insecurity as a constraint to the adoption of agroecological practices. The study of Mushagalusa *et al.* (2020) is also part of the same dynamic. These authors emphasized the influence of land tenure status. They argue that farmers who do not have secure and sustainable access to land are not always sure of benefiting from the results of agroecological investments.

The influence of farmers' perceptions

Farmers' perceptions of constraints and benefits remain a key factor determining their behavior and attitudes toward biological weed control practices. Indeed, the adoption of agroecological practices involves personal decision. The results of this study show that the decisions of the respondents are influenced by multiple factors. This implies that there is a diverse range of perceptions among the respondents. These results are consistent with those of Blake *et al.* (2007), who emphasize that farmers' perceptions of agroecological practices negatively influence their decisions to adopt them. In general, respondents indicated that, in addition to increasing the workload and the difficulty of transporting the pods to the fields, this practice requires the availability of the pods and agricultural equipment.The burying or processing of *P. biglobosa* pods is an intensive labor activity. Even for farmers equipped with carts, adopting *P. biglobosa* pods involves collecting the pods, transporting them, piling them up, and burying them, with results that some consider unsatisfactory. The respondents also perceive the use of *P. biglobosa* pods for weed management as a practice that promotes soil fertility restoration and increases crop yields. This perception is supported by the study of Coulibaly *et al.* (2019), which highlights the benefits of composting. However, the lack of financial support and technical guidance constitutes a constraint to the adoption of weed management practices using *P. biglobosa* pods.

Material and methods

Study area

The study area covers three administrative provinces : Comoé (10° 36' N, 4° 45' W), Léraba (10° 40' 00" N, 5° 12' 00" W) and Kénédougou (11° 25' 00" N, 5°00' 00" W) (Figure 3). The vegetation in these provinces consists of a mosaic of gallery and riparian forests, wooded savannas, and shrublands. The tropical climate is characterized by a dry season and a rainy season. The latter lasts from June to September, with rainfall (300 mm) generally more abundant than in the rest of the country. Agriculture and livestock farming are the main socio-economic activities practiced by the populations.

Data collection

Interviews were conducted in 18 villages in Comoé Province, 14 villages in Léraba Province, and Kénédougou Province. These are areas where some farmers adopted *P. biglobosa* pods into their weed management strategies. These sites are also areas where farmers mainly grow two improved varieties of maize, named wari and bondofa. The survey sample consisted of 262 farmers aged between 37 and 81, including 91 in Comoé province, 87 in Léraba province, and 84 in Kénédougou province. A survey method combining qualitative and quantitative approaches was used. On this basis, a structured questionnaire was drafted and sent to the respondents. Direct observations in the field provided a better understanding of farmers' level of knowledge of traditional weed management.

Statistical analysis

An econometric analysis using a logistic regression model was employed. The dependent variable of the model is the adoption of *P. biglobosa* pods for weed management. This is a dichotomous qualitative variable that takes the value 1 if *P. biglobosa* pods are adopted and 0 if not. This model is written as follows : Y=f(x,e), where Y is the dependent variable, taking the value 1 if the farmer uses *P. biglobosa* pods and 0 otherwise. X represents the matrix of explanatory variables accounting for the variation in Y, and e is the logistic error term. The Logit model is based on the maximum likelihood estimation method. Let P_i be the probability associated by the Logit model with the survey unit :

$$P_i = F(l_i) = \frac{1}{1+e^{-l_i}} ; \quad (1)$$

$$l_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \beta_3 X_{i3} + \ldots\ldots\ldots\ldots\ldots\ldots \beta_n X_{in}$$

I_i = vector, representing the characteristics of the survey unit and its decision; β_i = coefficients of the explanatory variables ; X_{in} = explanatory variables. A binary coding scheme (1 and 0) was used for the variables. The following variables were included in the model :

- Gender : This refers to the sex of the farm head or farmer. It is a binary variable taking the value 1 if the farmer is male and 0 if female.

- Age : This is the age of the farmer. It is a continuous variable. It is assumed that younger farmers are more dynamic in seeking information and adopt agricultural innovations more readily than older individuals.
- Education level: This is a binary variable taking the value 1 if the farm head has received formal education and 0 otherwise. Education level can be a determining factor in the adoption of agricultural innovations, as the intellectual capacity of an educated individual enables better understanding of decision-making processes.
- Farm size: This is a quantitative variable expressed in hectares. The larger the farm size, the more likely the farmer is to use conventional weed control methods. However, the availability of plant materials is one of the major constraints adoption.
- Land tenure: This is a binary variable taking the value 1 if the farmer inherits the land and 0 otherwise. Owning plots through inheritance is a factor that influences the farmer's decision.
- Training: This variable refers to knowledge received regarding the use of *P. biglobosa* pods. The variable takes the value 1 if the farmer has been trained and 0 if not.
- Membership in an association : This is a qualitative variable taking the value 1 if the farmer is a member of an association and 0 otherwise. Membership in a cooperative or association could influence the adoption of *P. biglobosa* pods.
- Perception of *weed* control : This is a binary variable taking the value 1 if positive and 0 if negative. This variable may influence the adoption of *P. biglobosa* pods either positively or negatively.

Descriptive analyses, including means, frequencies, and percentages, were performed on socio-economic characteristics. Econometric and descriptive analyses were conducted using R software, version 3.6.1. The P-value < 0.05 was considered statistically significant.

Conclusion

Training in biological control, membership in an association, age, farm size, land tenure, and education level are the determinants that significantly influence the adoption of *P. biglobosa* pods in agricultural systems. The identified benefits of using these pods include improved crop yields, increased nutrient content, and soil fertilization. The workload involved in biological weed management using pods, the unavailability of pods, the lack of agricultural equipment, and the difficulty of transporting the pods to the fields are identified as constraints to the adoption of *P. biglobosa* pods. Efforts are needed from policymakers to provide farmers with the necessary equipment and information. Association initiatives should also be encouraged to disseminate knowledge related to biological control. In the absence of such initiatives, structuring and organizing stakeholders involved in this field should be considered.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the results reported in this paper.

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