

Original Research Article

Effects of the agro-net technology on management and financial profitability of cabbage and pepper production systems in Benin

ABSTRACT

Aims: Chemical pesticides have been the main option for pest control adopted so far by vegetable growers in Benin, in spite of the health risks involved. In order to reduce such risks, researchers developed insect nets (called agro-net technology) as a means of physical pest control. This study aimed to analyze the financial profitability of the use of that technology in cabbage and pepper production, so as to advice on its better management and enable greater adoption.

Study design: Comparison was made of key indicators of resource management and financial profitability of a farm (productivity, profit ratio), among users and non-users of insect nets in the main production vegetable systems in Southern Benin.

Place and Duration of Study: Benin's National Institute of Agricultural Research (INRAB), in collaboration with the Faculty of Agronomic Sciences (FSA), from 2010 to 2011.

Methodology: Stratified and random sampling and a structured questionnaire were used to collect data from 205 farmers (including 20% insect net users and 80% non-users) in Mono and Couffo departments of Benin. Component analysis, K-Means, Cluster Analysis, Student T-test were used to identify the different vegetable production systems, and crop budgeting to evaluate and compare resource management indicators (labor and capital productivity) and profitability indicators (gross income, cost of production, net income, benefit/cost ratio) between these systems.

Results: Three vegetable production systems were distinguished in the study area: intensive system, semi-intensive system and extensive system. Only 20% vegetables growers use insect nets; they practice intensive and semi-intensive systems. The technology improved profitability only for cabbage in the intensive system where the benefit/cost ratio and capital productivity increased slightly by 15.6%. On the contrary, due to large increases in labor costs, pepper production using the nets in intensive and semi-intensive systems led to 42.8% and 25.7% profit reductions. Decreases in labor productivity worth 48.3% and 72.6% were also observed.

Conclusion: Overall, the agro-net or insect net technology increased labor costs while output values did not increase more than proportionally. The study provides evidence that an agricultural technology should substantially reduce labor costs and improve labor productivity before it can be widely adopted by farmers, especially the poor. Technology adaptation to crops' specific growth requirements is also needed to go beyond existing productivity and profitability advantages.

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39 *Keywords: insects net, agro-net technology, vegetables production system, financial profitability, labor*
40 *productivity.*

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43 1. INTRODUCTION

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45 1.1 Background and justification

46 Urban and Peri-urban Agriculture (UPA) is developing fast in sub-Saharan Africa due to
 47 urban population growth. It is a means to address diversity in urban food supply (Olanrewaju
 48 et al., 2004). Considering the low performance of rural production systems, UPA is presented
 49 as an option to face urban food insecurity (Tinker, 1998; Hounkponou, 2003), and vegetable
 50 production has become therefore an economic activity in that perspective (Singbo et al.,
 51 2004). In Benin, vegetable production is an important source of employment in urban and
 52 suburban areas, mostly in some rivers banks and valleys (Tiamiyou, 1995). It contributes to
 53 the creation of nearly 60,000 direct jobs and 25,000 indirect jobs (PADAP, 2003). Moreover,
 54 it plays an important role in the economy because of its high income potential. For this
 55 reason, the Government of Benin has identified vegetables as one of the twelve priority sub-
 56 sectors to be promoted in the Strategic Plan for Boosting the Agricultural Sector (2011). In
 57 addition to its social and economic importance, vegetable production is also useful to
 58 enhance food and nutrition security. Vegetables provide various nutrient supplements in
 59 Benin people's diets, which were previously mainly based on starchy foods (Amoussougbo,
 60 1993).

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62 However, the vegetable sub-sector in Benin is facing many difficulties. Previous studies
 63 (Tiamiyou, 1995; Adegbola et al., 2001) mentioned among the following main constraints in
 64 southern Benin: land scarcity, shortage of specific agricultural inputs (seeds and fertilizers),
 65 poor water control, lack of credit and pest attacks. Generally in sub-Saharan Africa, insect
 66 and mite pests are a major cause of yield loss in vegetable crops (CIRAD, 2008). To ensure
 67 pest control on these crops, farmers frequently spray chemical insecticides, often with
 68 increasing doses of unapproved products. This could lead to the presence of chemical
 69 residues in crops and in the environment (soil and ground water) on the one hand, and would
 70 affect both public and animal health on the other hand.

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72 The use of insect nets is expected to reduce the costs of pesticide use, thereby preserving
 73 the environment and public health. This article aims to assess the potential viability of this
 74 technology, by evaluating the financial gain of its use, compared to existing plant protection
 75 systems.

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77 1.2 Literature review

78 1.2.1 Brief overview of some key concepts

This study is about the profitability of cabbage and pepper in various vegetable production systems. Therefore the concepts of productivity, technical efficiency and allocative efficiency, and profitability are important, especially in the effort to understand how the first three are related to the last one. Before recalling those relationships, it is worth having a glance at the concept of production system and its implication for agricultural development interventions.

A production system is a particular arrangement of inputs, technical choice, and a combination of productions (Chombart Lauwe and Poitevin, 1957; Reboul, 1976). Vegetables are produced in various production systems. In Benin, they include: modern gardening systems as a market-oriented and continuous farming activity, lowlands or flood recession systems where vegetables are periodically cultivated, and urban and peri-urban systems where intensive, continuous or seasonal cultivation of vegetables and fruits is practiced (Tiamiyou, 2002). Based on many criteria including (a.o. crop area, type of irrigation system used, total amount of labor allocated to each crop, proportion of family labor used), Adegbola et al. (2004) identified five classes of farms in Grand-Popo district (Benin), including: "large producers, pump users"; "medium producers, Naguézé pump users"; "small producers, pump users "; "small producers, trained in gardening"; "medium producers with manual irrigation system". Singbo et al. (2004) and Adegbola et al. (2004) found that pepper ranks second among garden crops, and has therefore deserved a considerable attention among producers and government extension services. In vegetable seed production, pepper comes first with 72% of growers in the study area. Prior to profitability its production system, magnitude and frequency of consumers demand for pepper drive growers' choice for it. On the other hand, cabbage is a new vegetable crop being introduced there. However, it is the most exotic crop produced by 34% of growers (Koukponou et al., 2010).

The analysis of production systems can be used to identify regional priorities for rural investment and research. It can also help to identify and disseminate best practices in a production system and monitor their impact. Such analysis relies on the concepts of productivity, technical efficiency and allocative efficiency, and profitability, and will be of interest for the private sector and other non-governmental organization (Dixon and Gulliver, 2001).

Productivity is an output/input ratio, an input being a production factor (land, labor and capital). Inputs and outputs may be measured in physical or monetary terms, whereby physical productivity or economic productivity are distinguished, the latter offering better possibility for comparisons between enterprises in a same industry or across industries. Production efficiency is the relationship between output and each type of inputs. Marginal productivity expresses efficiency better, because the last unit of production factor used is a critical determinant of production decision-making. More broadly, optimum productivity is the possibility of a production system to provide goods at minimum cost. To achieve this goal, the system must use inputs in the most efficient manner to achieve technical efficiency, and choose a combination of factors that takes into account the benefits of inputs' relative prices and marginal productivity (allocative efficiency). Technical efficiency indicates the achievement of maximum output possible, while allocative efficiency expresses minimal cost of input (Upton, 1996).

The present study does not go into production functions' modelling, whereby allocative efficiency could be evaluated. It rather assess the productivity and financial profitability vegetable production in selected regions of Benin. Profitability is the "capacity" of invested capital to provide income. Profit is the rate of return on invested capital, and profitability expresses its magnitude as resulting from a certain level of management capacities and conditions. In order to survive, a firm must optimize the use production factors and derive substantial benefits. Profitability is the first necessary condition for such survival, it is the "raison d'être" of the firm. In other words, it is profitability that justifies and drives business. Profitability then represents the evaluation of the performance of resources invested by investors (FAO, 2005). Several methods can be used for calculating financial profitability, such as the internal rate of return (in the case of multi-year projects) or the benefit/cost ratio.

The adoption of a new agricultural technology depends on its profitability, which is the expression of many driving factors pertaining to the farm's business environment and farmers' subjective perceptions on technology characteristics (Honfoga, 1999, 2007; Baidu-Forson, 1995). Evaluating a technology's profitability can be approached at two levels of observation: the farm (financial profitability) and the community (economic profitability). Unlike financial analysis, economic profitability analysis addresses the community level and uses economic prices¹ to calculate the gains or losses of production or technology choices for society. It takes into account the effects exerted by policy decisions on individuals, environment and economy of the locality, as well as secondary and indirect effects of investment (William et al., 2002). Only financial profitability of vegetable production systems and its drivers will be assessed in this paper.

1.2.2 Some previous works on profitability of vegetables production in West Africa and Benin

Kouvonou et al. (1999) found that the vegetable sub-sector development in Togo is stimulated by an increase in unemployment rate among young men and women, a strong demand for produce, and an attractive production profit. The differences between types and kinds of growers can influence the mode of farm management in some cases, but they are not significant in most cases. However, men more than women substitute higher labor for fertilizer in the allocation of financial production resources. Still, average net monthly income of growers is as high as salaries of high-level employees in Togo's public administration. Therefore vegetable production is highly lucrative. However, it is also very sensitive to the use of organic and inorganic fertilizers, which may become inaccessible due respectively to scarcity (as result of non-systematic production and reliance on erratic harvesting of city wastes) and high prices of imported inputs.

Adegbola et al. (2004) assessed the financial profitability of vegetables in various production systems in southern Benin. For pepper production, highest profits were observed with "medium producers, Naguézé pump users" and "small producers, pump users " while for tomato, only "small producers,

¹ Economic prices are the prices and costs that reflect the objectives, resources and constraints of society. It illustrates an ideal situation in the overall economy, where markets are perfect and where the invisible hands (rather than the State) direct the allocation of resources.

157 pump users " had the highest profits. The use of an irrigation system and relatively manageable farm
158 size appear therefore to be critical drivers of vegetable production's profitability. Fanou (2008) also
159 evaluated the financial and economic profitability of improved technologies of tomato and cabbage
160 production in southern Benin, using the Policy Analysis Matrix (PAM) developed by Monke and
161 Pearson (1989). Surprisingly, they found that bio-driven improved technologies (improved varieties,
162 biological insecticides, modern irrigation system) did not generally improve the profitability of vegetable
163 production systems. Indeed, tomato production systems in shallows area with local variety and use of
164 cotton insecticide were more profitable than other systems, namely those using biologic pest control.
165 However, cabbage production systems that apply aqueous neem extract and use motorized irrigation
166 were more efficient. Therefore, there was no constant direction regarding the efficiency of vegetable
167 production systems that use biological pest control. Apparently, crop specificities in relation with soil
168 fertility requirement and inherent vulnerability to pest attacks (which would determine chemical vs.
169 biological pest control efficiency) are critical determinants of physical productivity, which is a
170 prerequisite for financial profitability. Basic yield determinants (site/soil fertility, water availability) seem
171 to have taken precedence over pest control methods in the total efficiency of those vegetable
172 production systems.

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174 Market demand is particularly critical for vegetable farming's profitability. For example, cabbage is the
175 vegetable that generates more income to growers, thanks to its trade intensity in the West Africa sub-
176 region and its greater easiness of storage than other vegetables (Adorgloh-Hessou, 2006; Fanou,
177 2008). One may also emphasize the need for growers to increasingly target certain market segments
178 (high-income and snobbish consumers) who have greater willingness to pay more than others for
179 biologically-produced crops. The use of bio-pesticides contributes to increasing its competitiveness in
180 Ghana (IITA, 2002). Hence, marketability (including product quality) is also a critical factor driving the
181 financial profitability of vegetable production systems.

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183 The present study is a contribution to both existing research on the economics of vegetables
184 production and technology adoption studies. It assesses the extent to which adoption of insect nets,
185 as an "improved" biological pest control technology, improves the profitability of vegetables' production
186 in Benin.

187 188 **2. METHODOLOGY**

189 **2.1 Selection of sites and crops**

190 A three-stage site selection was made to conduct this study. Firstly, the UPA/PAN² project intervention
191 areas were targeted as the study area. Secondly, sites where the vegetable program (PCM) of the
192 project conducted field trials and pre-extension tests were considered³. They include the localities of
193 Seme-Kpodji, Cotonou, Pahou, Ouidah in the Atlantic department; Lokossa Athiémé, Bopa,

² UPA/PAN: ... / Pesticide Action Network.

³ The PCM program was jointly conducted by the National Institute of Agricultural Research Benin (INRAB), the regional vegetable councils (CRM)) and the APECTETRA NGO.

Houéyogbé, Comé and Grand-Popo in the Mono department; and Dogbo, Lalo, Klouékanmey, and Aplahoué and Toviklin in the Couffo department. Thirdly, Mono and Couffo departments, where the agro-net technology has been first introduced, were selected because quantitative data on producers' knowledge about the technology were already available in the project's database.

Regarding crops' selection, acreage coverage and use of the agro-net technology were considered. Agricultural statistics of Mono-Couffo (2010-2011) indicate that tomato (44.6% of total garden crops area), pepper (30.2%) and leafy vegetables (16.3%) were the most produced vegetables. Insect nets have been tested in Benin first on cabbage, then on pepper and tomato. Hence the choice of cabbage and pepper for this study.

2.2 Sampling and data collection methods

The study sample was selected among vegetable growers of Mono and Couffo departments. Each of them must have been informed about the agro-net technology. Therefore, producers selected for the study sample were drawn from the list of vegetable growers who participated earlier to a training on pest control in vegetable production using insect nets on cabbage, tomato and pepper. As a result, the municipalities of Aplahoué, Athiémé, Bopa, Comé, Djakotomey, Dogbo, Grand-Popo, Houéyogbé, Klouékanmey, Lalo, Lokossa and Toviklin appeared as the localities where the study should be conducted. Two hundred and five (205) farmers were randomly selected as the study sample, after a stratification was made in each locality according to the earlier discrimination (experimenters or new practitioners, experiment observers or hesitant users). Finally, the sample is made of 80% of non-users (experiment observers) and 20% of users (experimenters) of the agro-net technology (Table 1). The proportion of users is low because the technology is new and is at its very early stage of adoption. A large proportion of non-users was included in the sample in order to capture reliable and representative data from growers of the two crops in the agro-net project area, and to arrive at relevant profitability values from non-users that can be compared with those of users.

Table 1: Structure of the study sample

Municipalities	Non users	Agro-net users	Total	Municipalities	Non users	Agro-net users	Total
Aplahoué	36	0	36	Grand-Popo	31	2	33
Athiémé	5	7	12	Houéyogbé	4	4	8
Bopa	8	1	9	Klouékanmey	4	5	9
Comé	25	5	30	Lalo	5	7	12
Djakotomey	0	3	3	Lokossa	3	4	7
Dogbo	35	3	38	Toviklin	8	0	8
Total Sample (number)	164	41	205				
%	80	20	100				

Source: Survey data, September-October 2011.

Semi-structured interviews with individual farmers and group discussions were conducted in August 2011 using an interview guide. In September-October 2011, a detailed questionnaire was used to elicit the data required for the analysis.

2.3 Methods of data analysis

First a typology of vegetable production systems was established to identify the relevant categories of vegetable growers, using the following criteria: area sown during previous crop year (2010), number of years of experience in the activity, household size, number of workers employed, costs of hired labor, seeds, fertilizers and pesticides used during the previous season, and age of the producer. Principal Component Analysis (PCA) and classification in dynamic clustering or K-Means Cluster Analysis were used to identify and describe the different vegetable production systems. K-Means helps to aggregate vegetable growers into different clusters, and PCA helps make the description of each group.

Then the profitability of different production systems obtained was evaluated and compared with the profitability of the use of insect nets. Financial profitability was first estimated for each class of production systems identified by the typology. Then, it was assessed by production system where the net is used. Finally, comparisons were made between non-users and users of the agro-net technology to identify the production systems that are more profitable. Crop budgeting was used to evaluate financial profitability. But there are several types of budgets, such as business budget (e.g. a crop), total budget (all crops planned) and partial budget (variable costs) (Coulibaly and Nkamleu, 2004). In our study, business budget or operating account was used to estimate the profitability of vegetable crops' production systems. Inputs include fertilizers, temporary wage labor, pesticides and seeds. Fixed capital consists of tools such as hoes, dabas, watering cans, shovels, wheelbarrows, rakes and machetes. Gross margin was calculated as gross output valued at farm gate prices minus input costs and other variable costs, and net margin is gross margin minus fixed costs. These costs were calculated as follows:

- variable costs (seed, fertilizer, pesticides, and labor wage) per unit area; variable costs resulting from non-monetary transaction were estimated by their opportunity costs.

- fixed costs are per unit area depreciation of all farm tools of more than one year lifetime (hoe, machete, watering pump and insect nets and their installation). The annuity by type of equipment (Am_i) was estimated by the following formula:

$$Am_i = n_i * P_i / D_i$$

where:

Am_i = annuity tools considered in the production of vegetable i ;

n_i = number of tools used by the vegetable grower in cabbage and pepper production;

P_i = unit purchase price;

D_i = lifetime of the tool.

In calculating gross output for each crop, we assumed that all harvest is completely sold at the selling price declared by the vegetable grower. The Student t test was used to see if there is a significant difference between existing production systems and new technology for average costs and margins per hectare. This test also contributed to identifying the most profitable production system. The most ubiquitous indicator of profitability is the benefit/cost ratio, i.e. the ratio between the net income or profit and total production costs. It was calculated to conclude about the profitability of the each crop by production system.

In order to deepen the analysis of financial profitability, labor productivity and capital productivity – with and without the use of insect nets – were used as indicators of economic performance of the identified production systems. They were calculated as follows⁴:

- Labor productivity = (Gross output - all costs except labor) / number of worker units
- Capital productivity = (Gross output - all costs except capital) / Capital

These formula are proxies of marginal productivities (i.e. marginal output of X / quantity of X). In the absence of production functions, marginal output of each production factor (X) was calculated as “Gross output – all costs except X”. This was done under the assumption that other factors are used at the threshold of zero profitability, i.e. their contribution to the total output is exactly equal to their costs. In the multiple factor production function, obviously this would not be the case.

Under that limitation, comparisons between production systems were then made to see the extent to which the use of the agro-net technology improves labor and capital factor productivity. Analysis of variance with the Fisher F test and Student t test were used to see if there is a significant difference between the ratios calculated.

3. RESULTS AND DISCUSSION

3.1 Typology of vegetable crop production systems and differential use of agro-nets

The typology of the vegetable production systems in the study area was established using the criteria previously mentioned. The Fisher F-test was used to identify the main discriminant variables. The most significant variables at the 1% level include: area sown in the previous year 2010, number of agricultural workers, costs of labor and cost of seeds, fertilizers and pesticides. Using the Principal Component Analysis (PCA) and classification by dynamic Clouds (K-Means Cluster Analysis), three production systems were identified: intensive production system, extensive production system and semi-intensive production system.

⁴ It is worth mentioning that number of workers is not exact measure of labor. Man-days is more appropriate and is calculated using as: Sum (number of workers*age class coefficient*number of days worked). This formula could not be used in this study because reliable data were not available on number of days worked and age class coefficients in vegetable production.

The intensive production system is practiced by producers in their sixties, with high purchasing power. They have good experience in vegetable production and possess large areas and use great quantities of inputs per unit cultivated area. Labor costs are important. The extensive production system is practiced mostly by young-like vegetable growers, with low use of production factors (land, labor and capital). The semi-intensive production system is in-between the previous two systems. Producers in this group are generally younger than large producers and older than small producers. Producers of the extensive system do not use insect nets, probably because of high costs associated with the use of technology. A simple structure of the study sample is presented in Table 2, without those resource endowment information.

Table 2: Distribution of vegetable growers by production system and use/non-use of insect net

Production systems	Without net	With net	TOTAL
Extensive	24,88% (51)	0% (0)	24,88% (51)
Semi-intensive	1,95% (86)	11,22% (23)	53,17% (109)
Intensive	13,17% (27)	8,78% (18)	21,95% (45)
TOTAL	80% (164)	20% (41)	100% (205)

Source: Survey data, September-October 2011

3.2 Comparison of farm resource management and financial profitability indicators

Table 3 shows that pepper and cabbage production is profitable in the identified systems. However, the intensity of use of production factors varies greatly from one production system to another. Highest margins were observed with the intensive system and the lowest with the extensive system. However, the benefit/cost ratio of the extensive system (4.74 and 3.54 for pepper and cabbage) was higher than that the other systems, indicating that both crops are highly and more profitable in that system. The limited or non-improved profitability in semi-intensive and intensive systems stems from higher production costs (4-7 times those of the extensive system) with the agro-net technology whereas crop yields and per unit output value did not significantly increase.

In pepper production insect nets are used only in experimental farms and nursery, and not in the real field (farm), probably because the plant's height is such that early installation of the nets – as it is recommended – would impede flowering and disturb the plant's development. Moreover, it would require more net rolls and higher and more arches for their installation. Overall, the use of the agro-net technology in pepper fields is time consuming and labor-demanding, meaning higher production costs than without it. Producers were therefore advised to limit the use of the net only in nursery for this crop. In the case of cabbage, the net is set in nursery and on-farm experimental fields because cabbage plants rest on the floor until flowering.

Some experienced vegetable growers claimed to be satisfied with the use of the net in pepper nursery. The agronomic advantages include protection of plants from damage caused by animals and crickets,

and stronger plants for transplanting. But they complained about the presence of whitefly that pass through the mesh, thus causing extra cost of purchasing insecticides for joint treatments. Indeed, according to Simeni Tchuinte (2005), in the field (i.e. real farms) pepper stands out among traditional vegetable crops but producers do not fully benefit from their investments because of diseases caused by insects.

Table 4 shows that gross outputs are significantly improved for both crops with the agro-net technology. However, the use of this technology requires significant initial investments, which producers in extensive systems cannot afford. That's the reason why the profitability analysis is limited to semi-intensive and intensive systems. It appears from this table that the use of insect net in intensive and semi-intensive systems for pepper production is not more profitable than old practices. The benefit/cost ratio is respectively 1.94 and 1.87 for the intensive and semi-intensive production systems without the use of the net, against 1.11 and 1.39 in the same systems with the use of the net, i.e. respectively 42.8% and 25.7% profit reductions. On the contrary, cabbage production under insect nets is more profitable with the nets in both systems. The benefit/cost ratio is respectively 1.86 and 1.87 for the semi-intensive production system without and with the use of the net. For the intensive production system, corresponding figures are 1.57 and 1.93. In addition, the use of net reduces pesticide costs. This result confirms previous findings (Martin et al., 2006; Assogba et al., 2010). Regarding economic performance, Table 3 also shows that labor productivity has not improved with the nets in both systems for cabbage and pepper production. Indeed, significant decreases in labor productivity appear between 'without' and 'with the technology' for pepper production in both semi-intensive and intensive production systems. Compared to non-users, decreases in labor productivity of users are 72.6% with the semi-intensive system and 48.3% with the intensive system. Corresponding figures for cabbage are 34.3% and 12.3%.

The reason is that the use of insect nets demands too much labor, and the recommended technical route is long and tedious. Likewise, the use of insect nets in pepper production does not contribute to improving capital productivity in intensive system and semi-intensive system. Only in cabbage intensive system is capital productivity significantly improved with the use of insect nets, from 2.57 to 2.93, i.e. an increase by 15.6%.

Table 3: Financial profitability and factor productivities of pepper and cabbage production systems

Items	Pepper			Cabbage		
	Intensive System	Semi-intensive System	Extensive System	Intensive System	Semi-intensive System	Extensive System
Gross income (Fcfa/ha)	2 696 761.2 ±517 626.1 ^a	1 552 576.8 ±832 979.6 ^b	870 626.3 ±58 689.4 ^c	3 576 617.1 ±156 768.1 ^a	3 196 595.06 ±414 982.02 ^b	2 616 194.8 ±171 369.7 ^c
Net Income (Fcfa/ha)	2 416 129.1 ±452 446.6 ^a	1 380 571.8 ±818 896.5 ^b	804 902.2 ±47 490.9 ^c	3 301 276.5 ±73 312.4 ^a	3 009 782.1 ±336 781.2 ^b	2 534 922.7 ±168 239.06 ^c
Total production Costs (Fcfa/ha)	1 293 187.2 ±263 219.4 ^a	709 978.1 ±91 325.2 ^b	169 855.8 ±35 679.01 ^c	2 104 291.6 ±795 918.6 ^a	1 621 611.9 ±743 441.6 ^b	716 653.4 ±358 201.9 ^c
Benefit / Cost ratio	1.87 ^a	1.94 ^b	4.74 ^c	1.57 ^a	1.86 ^b	3.54 ^c
Labor productivity (Fcfa/Manday)	4 085.92 ^a	3 238.19 ^b	3 562.14 ^c	5 784.61 ^a	4 708.15 ^b	8 030.55 ^c
Productivity of capital	2.86 ^a	2.94 ^b	5.74 ^c	2.57 ^a	2.86 ^b	4.53 ^c

Notes: a, b and c: level of significance 1%. The means are statistically different from one letter to another at the level of 5%.

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Table 4: Financial profitability and factor productivities of pepper and cabbage production systems with and without insect nets

Items	Pepper				Cabbage			
	Semi-intensive system		Intensive System		Semi-intensive system		Intensive System	
	Without net	With net	Without net	With net	Without net	With net	Without net	With net
Gross income (Fcfa/ha)	2 090 550 ±910 221.7	2 626 327 ±878 408	3 709 316.3 ±715 666.04	4 374 700 ±1 172 604	4 631 394.1 ±1 080 222.9	4 996 100 ±687 931	5 405 568.2 ±869 231.07	7 790 500 ±1 090 780
Pesticides (Fcfa/ha)	46 823.5 ^b ±10 005.2	33 206 ±16 ^a 194	66 420.3 ^d ±9 351.1	26 913 ^c ±11 550	113 080.4 ^b ±71 964.5	93 696 ^a ±62 048	204 600 ^d ±86 800	105 299 ^c ±83 025
Labor (Fcfa/ha)	113 448.3 ^b ±10 709.6	495 417 ^a ±103 503	412 536.9 ^d ±36 153.4	866 234 ^c ±179 408	321 225.1 ^b ±109 132.4	502 500 ^a ±187 285	331 370.5 ^d ±171 895.3	763 695 ^c ±291 923
Gross margin(Fcfa/ha)	1 552 576.8 ^a ±832 979.6	1 625 150 ^a ±463 746	2 696 761.1 ^b ±517 626.1	2 921 094 ^b ±264 223	3 196 595.06 ^b ±414 982.02	3 407 155 ^a ±287 970	3 576 617.1 ^d ±156 768.1	5 523 396 ^c ±162 930
Net margin (Fcfa/ha)	1 380 571.8 ^a ±818 896.5	1 382 650 ^a ±450 296	2 416 129.1 ^b ±452 446.6	2 540 762 ^b ±231 103	3 009 782.1 ^b ±336 781.2	3 252 264 ^a ±111 532	3 301 276.5 ^d ±73 312.4	5 133 071 ^c ±210 720
Total production costs (Fcfa/ha)	709 978.1 ^b ±91 325.2	1 243 677 ^a ±235 762	1 293 187.2 ^d ±263 219.4	1 833 938 ^c ±430 328	1 621 611.9 ^b ±743 441.6	1 743 836 ^a ±799 463	2 104 291.6 ^d ±795 918.6	2 657 429 ^c ±1 301 500
Cost / benefit ratio	1.94^b	1.11^a	1.87^d	1.39^c	1.86^b	1.87^a	1.57^d	1.93^c
Labor productivity (Fcfa/Manday)	3 238.19^b	1 875.36^a	4 085.92^d	2 754.66^c	4 708.15^b	3 504.25^a	5 784.61^d	5 152.34^c
Productivity of capital	2.94^b	2.11^a	2.86^d	2.38^c	2.86^b	2.87^a	2.57^d	2.93^c

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Notes: a and b: level of significance 5%; c and d: level of significance 1%. The means are statistically different from one letter to another at the level of 5%.

4. CONCLUSION AND POLICY IMPLICATIONS

Pepper and cabbage production is profitable in the three production systems, yet only the extensive system offers the most interesting benefit/cost ratio (greater than 3) for both crops. Vegetable growers in the extensive system do not use the agro-net or insect net technology because it involves high initial investments and costly labor use which those farmers cannot afford. The use of agro-net technology in semi-intensive and intensive systems did not improve the profitability of the two crops, except for cabbage in intensive system where the benefit/cost ratio is improved slightly by 15.6%. Likewise, labor productivity in pepper production decreased by 72.6% with the semi-intensive system and 48.3% with the intensive system. The study therefore recommends that vegetable growers adopt the technology for cabbage – and maybe other crops with flat geometry spreading on the floor – in order to improve the yields and quality of the crops through healthy avoidance of insect attacks. Considering the drudgery of work and high labor costs involved in applying current recommendations for using the technology, it appears that correction is required on the technical specifications (the net's design, arches/skeleton for installing it, and optimal adaptation of the technical route) of the technology to producers' farming practices. Only then can the technology be widely adopted, because it will become financially accessible to the extensive system growers (currently 80%) who will then move from their current status of non-users to that of users. They will also derive substantial profits while offering healthy vegetables to fulfill the existing high demand in domestic and regional markets.

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