



Wrap & Plant Technology: An Innovative and Cost-Effective Method for Seed Yam Treatment for Nematode Control in Fields

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ABSTRACT

In West Africa, seed yam represents an important source of nematode inoculums in yam fields and a major cause of the disease perpetuation. To enhance nematode control on yam (*Dioscorea* spp.), a pilot participatory field evaluation was conducted in Benin on nematode control potential of abamectin-treated banana paper (treatment A) using seed wrap method. An additional seed yam wrapped with untreated paper (treatment B) is also considered. Both treatments A & B are then compared to unwrapped seed yam representing the farmers' practice (FP). In each field, plots are arranged in a randomized complete block design with five replicates. The effects of seed yam treatment on nematode control in fields, gustatory qualities of yam tubers, and both social and profitability studies of the technology were assessed. In the present paper, only the study related to the profitability based on the Net Margin (NM) and the ratio Cost/Profit is presented. Results reveal advantages of treatments A and B over (FP). In fact, production statistics from treatments A and B are significantly higher than those from (FP). Based on the "willingness to pay" approach, the profitability study shows that treatment A has a Net Margin of approximately 153.7% that of (FP). Concerning the ratio Cost/Profit, 100 FCFA (West African CFA franc) spent in yam production using this new technology generates around 79.3 FCFA against 59.9 FCFA for (FP). Despite the success of this pilot study, input prices must be monitored before scaling up this innovation to the other agro-ecological regions of Benin.

Key-words: Nematode control, *Dioscorea* spp., cost effectiveness, input prices, Wrap & plant technology, Benin

INTRODUCTION

The targeted research seeks to improve agricultural productivity of yam, and therefore its quality, although agricultural scientists admit that end-users in general and producers in particular are more concerned with culinary and tasting advantages [1; 2]. It is then relevant to involve the majority of end-users in perceptive evaluation of a new technology on yam in order to assess performance at different phases: vegetative, harvest, food processing, and tasting. From the beginning of the process - wrapping of seed yam cv. Klatchi with banana-fiber paper impregnated with micro-doses of abamectin- to the end - various dishes made from yam, it

should be clear and straightforward that the new technology overshadows farmers' practices. However, as reference [3] put it, performance of an agricultural technology does not rely solely on end-users' adoption model, but more importantly on so-called spatial and environmental heterogeneities. Thus, piloting new agricultural practices on three different sites should not only reveal end-users' sensitivities but also ecological variability [4]. The question here is not if banana-fibre paper and abamectin are physically and financially accessible to farmers, but if cost-effectiveness is ensured. The answer should be sought on both agricultural researchers and farmers' sides before any kind of dissemination of the technology to producers. The team of researchers seek to emphasize various advantages of the new agricultural practices with respect to pest control and quality enhancement on the one hand and cost-effectiveness on the other. The technical-economic analysis of agricultural innovation is used to assess the relative advantage of wrapping of seed yam cv. Klatchi with banana-fibre paper impregnated with micro-doses of abamectin over farmers' practices.

This paper is organized in four sections: assessment of perceptive adoption; materials and methods; insights on the results; and discussion of the findings.

ASSESSMENT OF PERCEPTIVE ADOPTION

Perception and adoption of agricultural innovation

The system combining "zero" tillage with intermittent irrigation in order to control malaria in rice-producing areas caught our attention for the interdisciplinary teamwork needed for the development of new agricultural practices [5; 4]. This system showed that several disciplines contribute to the making of the adoption process, each one looking at it through its own prism. These disciplines include economics, sociology, agronomy, crop protection, and others.

Economists look at agricultural innovations with respect to the economic development of societies. From such a view point, innovation is the meaning of progress, of sustainable growth, and sustainable development. Accordingly, economic advantages explain adoption of innovations [6].

Sociologists rather analyze circumstances that lead to adoption rather than the innovation itself. For instance, references [7; 8; 9] were most involved in studying the performance of an innovation. Reference [8] defined innovation as an idea, a practice, or an object that was perceived to be new by individuals. The author suggested that innovation was relative and a function of space, time, and actors. According to [10], spatial variability should be emphasized: the so-called spatial and environmental heterogeneities [3]. Innovation was meant for problem resolution in the society by the adoption of a new practice or a new good. Therefore, needs and problems determined the adoption rates of innovations. That was the rationale of why, in the search for solutions, [11] recommended priority ranking of the problems from the outset.

To the point of view of agronomists, they consider agricultural innovation to be a new practice, a current but modified practice, or equipment that reduces work strains and allows improvement of productivity [12].

Crop protectionists envision more the extent of damage to crops [13; 14] or to people [5]. As soon as those damages are significantly reduced, the innovation has a potential to be adopted.

Despite the wide ranges of sociological studies on innovations, authors failed to capture the active role of end-users in the process but did admit that end-users modify or unpack innovations [15; 16]. They also stressed sociological inertia and backward attitudes of farmers that still prevailed in rural areas [17; 18]. How much farmers gain in the adoption process was not yet considered. That is the rationale of why the adaptation of full-fledged performance criteria from the outset, by which both the team of researchers and the group of farmers abide, would ease the dissemination process.

Performance criteria for the adoption of agricultural innovations

Performance criteria include efficacy, efficiency, effectiveness, and relevance [15]. If efficacy entails the existing link between outputs and objectives, efficiency refers to the unit cost of production. Both criteria are difficult to adapt to farmers' circumstances and the R&D settings of these experiments. From farmers' perspectives, experiment objectives are set up by the team of researchers and do not include their responsibilities. Nor can farmers endorse an efficiency principle related to the minimal unit cost.

Effectiveness, on the contrary, is founded on the degree to which end-users are satisfied given the results achieved [19]. Farmers were asked to contribute labour and their lands. They were then concerned with the extent of satisfaction in terms of achievements if opportunity costs were lessened, or otherwise.

One more criterion that should be considered is whether the innovation is relevant or not. Given the background of the nematode attacks depicted by [20] and [21], it seems unlikely that farmers disagree with the need for such an innovation.

Among other factors of adoption, references [7; 8; 9] failed to acknowledge backward and forward linkages such as the initial cost of the innovation, factors linked to risks, and institutional factors (credit outlets, markets, *etc.*). There is another factor that underlines most rejections of agricultural innovations: the labor management system [22]. The agricultural production schedule is tightly compressed. Most farm operations must be conducted at the same time within a short period.

MATERIALS AND METHODS

This research is carried out ex ante introduction of wrapping of seed yam cv. Klatchi with banana-fibre paper, impregnated with micro-doses of abamectin or not, in order to assess end-users' perception, practices of nematode control, and profitability of the new agricultural technology in Benin. It is intended to provide insights into "quality-oriented" yam production perspectives in Benin and other West African countries like Nigeria, Ghana, and Togo. The rationale here is to shed light on the research process as well as on the research results [23]. Henceforth, the following materials are considered in line with the indicated methods.

Materials

Two new practices are considered versus farmers' practices in three localities at the centre of Benin: Savalou, Savè, and Glazoué districts. Treatment A (wrapping of seed yam cv. Klatchi with banana-fibre paper impregnated with micro-doses of abamectin) and treatment B (wrapping of seed yam of cv. Klatchi using banana-fibre paper alone) were the two agricultural innovations. For a detailed description of the technology, see [24].

A record guide was installed with 17 farmers, producers with experimental fields, in order to record cost aspects. Research assistants were assigned the follow-up of the producers, under close supervision of a field agent (Counsellor in agricultural production from agricultural extension, research technician, research assistant R&D from agricultural research institution, laboratory assistant from Higher Education Institutions). It should be stressed that the research units chosen were 17 experimental farmers with one yam field each. However, for information at the scale of the localities, *e.g.*, labour cost and the approach based on the willingness to pay, 19 other participants were selected following the profiles described below.

Yam producers not involved in experiments, mainly male producers (n= 4);

Yam traders present on most local yam markets, mainly female traders (n= 5);

Yam food retailers with experience in various yam dishes, mainly female actors (n= 5); and,

Yam consumers, mainly female actors (n= 5).

Sampling and Data Collection

A combination of 17 yam producers and 19 other end-users was involved in providing critical information on the management and farm budget records on the three sites (localities). Data collection covered the perception of participants with respect to agro-morphological descriptors, the constraints when harvesting yam tubers, the ease at which yam processing was conducted, and the quality of derivative meals. Participants then compared costs and profits of the improved yam practices with those of farmers' practices (FP) through an agricultural budget.

Methods and data treatment

Recorded data were targeted to the calculation of net margin for each experiment. This is to say three (3) net margins (treatments A, B, and FP) for each producer and 51 net margins in total. Quantitative methods of analysis were handled in general for the estimates of production and net margins. Nonetheless, qualitative information is useful in order to provide a good understanding of both institutional and cultural dimensions. The rationale of targeting net margin is twofold: i) It is intended to stimulate the recording reaction on the side of farmers; ii) It is also to appeal to the economic concerns of various researchers, whatever their disciplinary background. Consequently, agricultural innovations should be financially profitable at the research gate compared to farmers' practices before being eligible for dissemination. Accordingly, yam-based agricultural innovation would be profitable if the net margin is positive.

The analysis of net margins is pursued by inquiring into the equity of distribution with respect to each agricultural technology. In this vein, average net margins are calculated (P_i), and net margins are compared one to the other. For this purpose, a variance analysis (ANOVA) with one factor classification is carried out.

The null hypothesis is $H_0: P_1=P_2=P_3$ (all three net margins are equal) against H_1 : at least one P_i different from the others (one margin is different from the others).

The probability of having an identical net margin for the three treatments is then calculated and compared to the theoretical value at 5%.

The net margin is calculated with Excel, v 2013, while variance analysis (ANOVA) is performed with the software MINITAB Release 14.

The making of an agricultural budget

Agricultural budgets create data for cost-profit analysis. This is set in order to provide information on the profitability of agricultural innovations, crops, and the farm as a whole. Reference [25] recommended three methods for assessing the financial profitability of production systems: crop budget, partial budget, and total budget. This tool was used by [26] in order to assess the financial profitability of improved technologies on black-eyed pea production, by [27] in order to evaluate the impact of new agricultural technologies for black-eyed pea production on household revenue, by [28] to evaluate the profitability of legume production systems in Djougou, and by [29] in the comparative analysis of revenue and its distribution among tomato producers.

A crop budget covers the costs of the agricultural inputs and the estimates of the revenues of the product valorised at farm gate. Factors involved in the agricultural productions include land, labour (family and casual labour), pesticides, and seeds. The fixed assets are items such as hoes, watering cans, shovels, wheelbarrows, warping-combs, motor-pumps, and boring-water. However, in this research, there is not much equipment needed: hoes, warping-combs, *etc.* The gross margin is the difference between the gross production valorized at farm gate prices and the input costs.

The calculation of net revenues/net margins is as follows:

Gross Production (GP) in West African CFA (pegged with 1 euro = FCFA 655.957)

GP is the indicator of the total physical quantity of production for the season, expressed in kg of yam per producer. The GP considered here is calculated on the basis of the price obtained by the producer for the quantity that is sold.

Price estimates in FCFA

Yam farm gate prices are consensually proposed by traders. Then, following a single bounded approach, other participants agree on a unique price per treatment. The average price considered in the calculation of yam revenue is weighted by the quantities. It is the same for the calculation of input prices (seeds, banana paper, and abamectin, the nematode control product) that enter the production of yam. Prices are calculated as:

$$P_p = \frac{\sum P_i Q_i}{\sum Q_i}$$

P_p : Prices weighted by quantities in FCFA/Kg;

P_i : Price of input i ; and

Q_i : Quantity of input i used in the production process.

Revenue per unit area (ha) of cultivated yam in FCFA/ha

Revenue (R) here is calculated from the average yam yield (Rd) multiplied by the average price ($\bar{P}$): $R = Rd * \bar{P}$. In the absence of record books, the average price is calculated as:

$$\bar{P} = (P_{\max} + P_{\min})/2, \text{ with:}$$

$P_{\max}$ = Maximal price obtained from sale; and

$P_{\min}$ = Minimal price obtained from sale.

Estimates of variable costs (VC) in FCFA

$VC = \sum VC_i$, with VC_i the value in FCFA/ha of variable cost i.
i= labour, seed yam and additional input costs.

Labour: two types of labour are considered: family and casual labor. For each cultivating operation, the quantity of labour is recorded according to a specific guide. Details are the number of workers, whether or not they are family members, and the daily length (time) of their work. The total length of work for each cultivating operation and for each type of labour is then calculated. The total labour (TL) in male adult equivalent is then derived as follows:

$TL = 1 * (\text{Number of male adults}) + 0.75 * (\text{Number of female adults}) + 0.5 * (\text{Number of children})$
The conversion coefficients are adapted from Norman (1973). The conversion of total labour in male adult equivalent day or man day (M.D) is obtained by multiplying the total labour by the total working time (WT) in hours divided by 8 hours:

$$WT (M.D) = \frac{TL * WT}{8}$$

All labour is priced at the rate at which it would cost to hire it. This assumes that the opportunity cost of family labour is the same as the wage of hired labour, which in fact is unlikely.

Seed yam: Quantities and prices of seed yam are collected from producers, specifically the average prices are weighted by quantities purchased.

Seeds, banana paper, and abamectin: quantities of seeds used and prices of various inputs are collected from producers, except those of banana paper and nematode control product. Weighted prices are used in the calculating formula.

Estimates of Fixed Costs (FC)

Land rent: amount for rent is obtained from farmers who rent their land. For producers who inherit or buy their land, the average rent applied in the locality is considered.

Given the nature and types of fixed assets, a linear calculating method is most adapted to annual depreciation. The costs of the tools and equipment and their life spans are collected from farmers. Depreciation (D_p) is obtained as follows:

$$D_{p_i} = \left(n_i * \frac{P_i}{D_i} \right) * T_i, \text{ where:}$$

D_{p_i} = depreciation of the tool/equipment for producer i;

n_i = number of the tool/equipment used by the producer;

P_i = unit price;

D_i = length of time that the tool/equipment could be used by the producer;

T_i = length of time that the use of the tool/equipment is actually devoted to yam; and

$FC = \sum FC_j$ with FC_j the value of fixed cost j as a contribution to yam production in FCFA/ha.

Gross Revenue/Gross Margin and Net Revenue/Net Margin

Gross Revenue (GR), delineated as Gross Margin (GM), is the difference between GP valorised at farm gate price and variable costs (VC). This is calculated as follows:

$$GR = GM = GP - VC$$

Net Revenue, or Net Margin, is the difference between GR and related FC.

$NR = NM = GP - TC = GP - VC - FC = GR - FC$, with TC = total cost.

The concern here is not for a cropping system or several crops, but only for yam (Coulibaly & Nkamleu, 2004).

RESULTS

Estimates of variable and fixed costs

These costs include labour, seed yam, paper fibre, abamectin, land rents and depreciations of agricultural equipment.

Estimates of variable costs

– *Labour costs*

Labour is essentially casual and, in the case of family labour, there is a consensus to treat it as casual labor. Various labour costs are illustrated following the three treatments in Table 1.

Table 1: Estimates of labour costs in FCFA/ha

Parameters	Treatment A	Treatment B	Treatment FP
Average	366,850	366,850	355,350
Standard error	90,714	91,252	91,252
Maxima	546,919	546,919	533,897
Minima	234,394	228,606	215,584

Source: Field data, November-December (2017)

Treatment A: wrapping seed yam cv. Klatchi with banana-fibre paper impregnated with micro-doses of abamectin

Treatment B: wrapping seed yam of cv. Klatchi using banana-fibre paper alone

Treatment FP: Farmers' practices

Table 1 depicts labour cost estimates for the three treatments. It shows a significance difference between Treatment A & B with treatment FP, because of additional labour for wrapping the seed.

Table 1 illustrates that treatments A & B (366,850 FCFA/ha) require more labour than farmers' practices (355,350 FCFA/ha). The difference stems from the additional work (10 MD/ha) needed to wrap seed yam cv. Klatchi with banana-fibre paper, and impregnate with micro-doses of abamectin for treatment A. In fact, labor costs for farmers' practices represent 97% of the costs of treatments A and B.

– *Estimates of seed yam costs*

Seed yams are equally used in the three treatments (A, B, FP) for at least three reasons. First, all experiment plots cover a standardized area. Second, seed yam cv. Klatchi is the only promoted variety. Third, this variety is widely cropped by the majority of farmers in the experiment localities. Thus, table 2 shows the same values for all treatments.

Table 2: Estimates of other variable costs in FCFA/ha

Parameters	Treatment A	Treatment B	Treatment FP
Average seed yam costs	763,840	763,840	763,840
Average additional input costs	183,600	173,600	-
Average total variable costs	1,314,290	1,304,290	1,119,190

Source: Field data, November - December (2017)

Treatment A: wrapping seed yam cv. Klatchi with banana-fibre paper impregnated with micro-doses of abamectin

Treatment B: wrapping of seed yam of cv. Klatchi using banana-fibre paper alone

Treatment FP: Farmers' practices

Table 2 depicts the variable costs of the three treatments. In terms of additional input costs, Treatment A hits ceiling while treatment B follows, and treatment FP has no additional input costs.

– ***Estimates of additional variable costs of the new technology***

In the wrap & plant technology, additional variable costs entail the cost of banana paper and the cost of abamectin per treatment (*cf.* table 2). For each unit of area (ha), 6,944 yam seeds are wrapped in paper (impregnated with abamectin for treatment A) or not. It is instructive to notice that both abamectin and banana-fibre paper account for variable costs, since they all disappear after usage. Banana paper is estimated at 25 FCFA per unit (referred to mound), while an equivalent input, pesticide essentially made of abamectin and called "Acarius®", is sold for 10,000 FCFA/litre. It is instructive to see that the whole litre is much more than needed for the prescribed micro dose, but contingencies are planned for because of 6,944 manipulations/ha.

– ***Estimates of total variable costs in FCFA/ha***

Because of the new technology, total variable costs of treatment A and B escalate and amount to 117.43% and 116.54% of variable costs of treatment FP, respectively (*cf.* table 2). It should be stressed here that additional costs related to the new technology involve new inputs such as banana paper and abamectin as well as operating labour in order to wrap and plant.

Estimates of fixed costs

– ***Estimates of land rents***

As shown in table 3, the average rent for land is 19,412 CFA/ha in the experiment localities. Given that cost, it could be assumed that yam cultivating lands are not a limiting factor.

Table 3: Estimates of average fixed costs in FCFA/ha

Parameters	Treatment A	Treatment B	Treatment FP
Average land rents	19,412	19,412	19,412
Depreciations of agricultural equipment	68,735	68,735	68,735
Average total fixed costs	88,147	88,147	88,147

Source : Field data, November - December (2017)

Treatment A: wrapping of seed yam cv. Klatchi with banana-fibre paper impregnated with micro-doses of Abamectin

Treatment B: wrapping seed yam of cv. Klatchi using banana-fibre paper alone
 Treatment FP: Farmers' practices

Table 3 depicts the estimated average fixed costs which are similar for all three treatments.

In those localities, most farmers inherit their land, but a few rent their cultivated areas. For a standardized approach of analysis of the agricultural innovation, the average land rent in the localities is considered.

– ***Estimates of depreciations of the agricultural equipment***

It is important to notice that this innovation hardly requires new agricultural equipment. In economics, such an innovation is said to be neutral with respect to capital, one important production factor. That is the rationale as to why fixed costs are equal for treatments A, B, and FP (*cf.* table 3). The low level of depreciation portrays, however, the traditional agricultural systems that are still prevailing in the experiment localities. Those costs are calculated for the cultivation period.

– ***Estimates of total Fixed Costs (FC) in FCFA***

The total FC constitute the sum of land rents and depreciations of agricultural equipment (*cf.* table 2).

Estimates of total costs in FCFA

Total VC and total FC are added to get total costs (*cf.* table 4). The ratios of escalation of total costs for treatments A and B compared to treatment FP do not diverge much from those of total VC, 116.16% and 115.33%, respectively. This indicates that total costs are largely represented by total VC.

Table 4: Estimates of total costs in FCFA/cultivation period

Parameters	Treatment A	Treatment B	Treatment FP
Average	1,402,437	1,392,437	1,207,337

Source: Field data, November - December (2017)

Treatment A: wrapping seed yam cv. Klatchi with banana-fibre paper impregnated with micro-doses of abamectin

Treatment B: wrapping seed yam of cv. Klatchi using banana-fibre paper alone

Treatment FP: Farmers' practices

Table 4 indicates the total costs for each of the three treatments. The costs for treatment A are the highest, followed by those of treatment B and treatment FP.

Profitability analysis

Both agronomic and financial analyses are carried out.

Agronomic results (yield per treatment)

Table 5 depicts the average yield per treatment for the 17 experimental farmers' fields. Yield is used to report the total quantity of tuber per unit of area (ha) and per treatment.

Table 5: Estimates of tuber yields in kg/ha

Parameters	Treatment A	Treatment B	Treatment FP
Average	14,442	13,634	12,872
Standard error	1,487	1,388	1,512
Maxima	17,516	16,358	16,030
Minima	12,396	11,992	9,858

Source: Field data, November - December (2017)

Treatment A: wrapping seed yam cv. Klatchi with banana-fiber paper impregnated with micro-doses of abamectin

Treatment B: wrapping seed yam of cv. Klatchi using banana-fiber paper alone

Treatment FP: Farmers' practices

Table 5 provides estimates of tuber yields after the experiments. The estimates are significantly different one from the other.

As shown, yield parameters are in favour of treatment A with 14,442 kg/ha. Yields range from 12,396 kg/ha (minima) to 17,516 kg/ha (maxima). Strikingly, treatment FP, with an average yield of 12,872 kg/ha, is 12% short of the yield of treatment A. However, yield is not targeted through the present innovation: quality is the concern. Variance analysis (ANOVA) of the yam yields of all 17 experimental farmers' fields reveals that there is a significant difference between the average yields for the three treatments on one side and that any difference observed relative to farmers' practices is not due to hazard ($F = 4.89$; $ddl1 = 2$; $ddl2 = 48$; $p = 0.012$ at 5%; see Table A1 in appendix), on the other side. Treatment A, with apparently higher yields, produces high-quality yam publicly celebrated by participants. In the same vein, yield maxima of treatments A and B provide insights on the potentials embedded in the present agricultural innovation.

Financial results

Figure 1 illustrates price differentials going from yam for treatment A to yam for treatment FP.

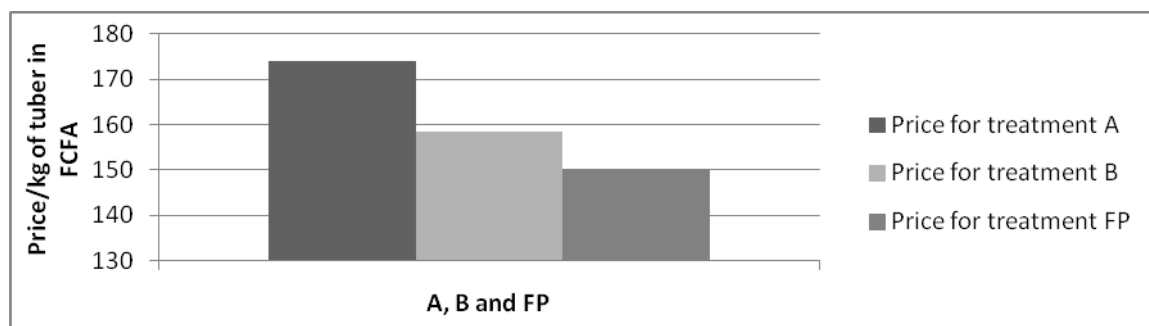


Figure 1: Price variations following tuber quality

Source: Field data, November - December (2017)

Figure 1 illustrates price differentials going from yam for treatment A to yam for treatment FP. For financial analysis purposes, three production factors are introduced: seed yam, agricultural inputs, and labor. Recall that GP is put for the total physical quantity of production valorised at

farm gate price, expressed in FCFA/ha. Farm gate prices are obtained through a process involving the "willingness to pay" approach.

In the experiment localities, yam is sold by weighing product on a balance outlet and per kilogram unit. Yam from treatment A ranks higher in price with its higher quality. Recall that 19 more participants, in addition to the initial 17 experiment farmers, bid prices according to the quality and the ensuing storage and culinary externalities of the yam output.

Yam tubers from treatment A are priced 10% and 16% higher than tubers from treatment B and treatment FP, respectively. Prices vary from 150 FCFA/kg for the lowest quality to 180 FCFA/kg for the highest quality. Tubers from treatment B are a little (6%) above prices of those from treatment FP.

Estimates of GP for the three treatments

As mentioned earlier, yams from treatment A are of better quality compared to those from treatments B, which are better than from FP. In addition, yam yield from treatment A is significantly higher than that from treatment B and henceforth that from treatment FP. Following the same logic, GP of treatments A, B, and FP range from the highest to the lowest.

Table 6: Estimates of GP for three treatments in West African CFA/ha

Parameters	Treatment A	Treatment B	Treatment FP
Average	2,514,517	2,160,952	1,930,835
Standard error	258,957	220,017	226,758
Maxima	3,049,711	2,592,743	2,404,500
Minima	2,158,268	1,900,732	1,478,700

Source: Field data, November - December (2017)

Treatment A: wrapping seed yam cv. Klatchi with banana-fibre paper impregnated with micro-doses of abamectin

Treatment B: wrapping seed yam of cv. Klatchi using banana-fibre paper alone

Treatment FP: Farmers' practices

Table 6 illustrates estimates of Gross Production (GP) for the three treatments in FCFA/ha. The highest values are for treatment A, followed respectively by treatment B and treatment FP.

Estimates of Net Margins for each treatment

Table 7: Estimates of Net Margins following three treatments in FCFA/ha

Parameters	Treatment A	Treatment B	Treatment FP
Average	1,112,080	768,515	723,498
Standard error	258,957	220,017	226,758
Maxima	1,647,274	1,200,306	1,197,163
Minima	755,31	508,295	271,363

Source: Field data, November - December (2017)

Treatment A: wrapping seed yam cv. Klatchi with banana-fibre paper impregnated with micro-doses of abamectin

Treatment B: wrapping seed yam cv. Klatchi using banana-fibre paper alone

Treatment FP: Farmers' practices

Table 7 provides insights on the Net Margins of all three treatments in West African CFA.

The average net margins are 1,112,080FCFA/ha, 768,515FCFA/ha, and 723,498FCFA/ha for treatment A, B, and FP, respectively. It appears that treatment A has the highest net margin

Comparing Net Margins for the three treatments

Variance analysis (ANOVA) of the Net Margins of all 17 experimental farmers' fields reveals that the average Net Margins are statistically different one from the other for the three treatments ($F = 13.81$; $ddl1 = 2$; $ddl2 = 48$; $p = 0.000$ at 1%, see Table A2 in appendix). This difference could be attributed to the differential agricultural techniques separating farmers' practice from treatments A and B. It then appears that the additional costs of production due to "wrapping of seed yam cv. Klatchi with banana-fibre paper impregnated with micro doses of abamectin" can easily be afforded, and treatment A is the best practices to offer from that point of view. Cost effectiveness can then be assumed, as soon as the average Net Margin of treatment A amounts to 153.71% that of treatment FP. Note that the Net Margin of treatment B is just 106.22% that of treatment FP.

The total costs of treatment A are 116.42% over those of treatment FP and, more importantly, the total costs of treatment B are 115.58% over those of treatment FP. The rationale of this comparison lies in the fact that treatments A and B should catch up the additional costs, providing that Net Margins of both are more than 116.16% and 115.33% over that of treatment FP, respectively. Therefore, the approach based on the Net Margins does not tell the whole story.

Comparing cost-profit ratios for all three treatments

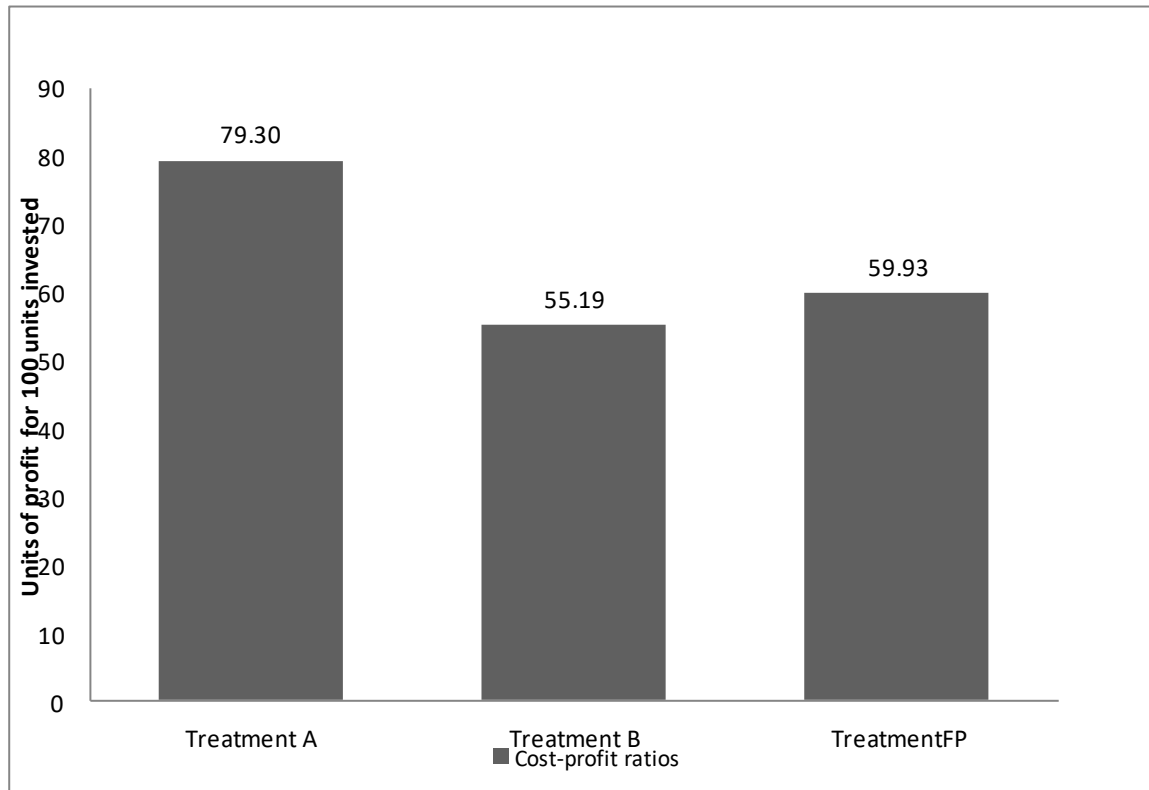


Figure 2: Cost-profit ratios for treatments A, B, and FP
Source: Field data, November - December (2017)

Figure 2 depicts evidence that treatment B is worse off compared to treatment FP. With doubts on the profitability of treatment B, it is interesting to inquire into the cost-profit dimension of the profitability analysis, as shown in Figure 2.

For hundred units invested, the average cost-profit ratios are 79.30%, 55.19%, and 59.93%, respectively, for treatments A, B and FP. More importantly, treatment FP generates more profit for farmers than treatment B, while the Net Margin of treatment B is higher than that of treatment FP.

DISCUSSION

Quantitative versus innovative qualitative improvements on yam

Two kinds of research applications are available in agriculture: the first is of genetic dimension, while the second fits in agricultural practices [4]. Each one of the two kinds has its advantages and its disadvantages. The wrapping of seed yam cv. Klatchi with banana-fibre paper impregnated with micro-doses of abamectin or not is of the dimension of improved agricultural practices. As such, it is prone to ecological variability [3]. That is the rationale underlying the challenging agronomic results achieved by treatment FP in the presence of treatments A and B. The same variability was found by [17; 18] for the introduction of new varieties of maize; the findings questioned the division between a genetic type of innovation and a type based on agricultural practices. It appears clearly that whatever the types, environmental variability marks its performance.

With respect to end-users' perception on agronomic performance, this differs from researchers to farmers [1]. From the point of view of farmers, their practices achieve higher outputs compared to the proposed treatments. Reference [30] reported the same feelings that hindered adoption of a new technology in Kenya. For researchers, on the contrary, the adoption is founded on the differential of prices due to quality performance of the outputs [31]. Are both groups looking at the same direction? The answer is not straightforward. Farmers who usually sell the bulk of their yam at harvest hardly care about quality [32]. Obviously, farmers other than subsistence farmers have a lot to gain from the present innovation, this is to say farmers who can afford to wait for better opportunities on the market [33; 34]. One way out of the dilemma is also the creation of an innovative business of ready-made treated seed yam with a new class of rural entrepreneurs [35]. A circular economy approach implying the role of cooperative of producers [36], or actors' innovation platforms as a tool for improving agricultural production [37], would also prompt the dissemination of the agricultural technology. What is the lesson to be learned is the creation of a network of treated seed yam to facilitate the dissemination of the technology "Wrap & plant" as expounded in [38].

The trap of the willingness to pay: overestimated versus underestimated prices

There are two assumptions on the willingness to pay: the first one is relative to prices at which yam product can be sold at farm gate, given its quality; and the second, more implicit, is relative to the willingness of farmers to pay the initial costs of the innovation. The first assumption entails two setbacks: overestimating prices as well as underestimating them. Before hand, is the approach put to use for the willingness to pay helpful and relevant?

Using a single-bounded approach to the willingness to pay requires a large sample of participants for efficient estimates rather than the panel of 36 participants at hand [39]. The rationale is to not put too much emphasis on the willingness to pay, while cost effectiveness is the concern. Therefore, the simplicity of one bid auction undertaken is just satisfactory. However, announced certified prices before the production are more inciting to adopt the agricultural technology [40] than prices from hypothetical bid auctions undertaken in researcher-managed conditions.

Underestimating prices: prices of agricultural goods used to be depressed because of both rural urban bias on one side [41] and the deterioration of terms of trade on the other [39]. Reference [42] also showed that willingness to pay estimates from the choice experiment were lower than consumers' average auction bids. Of course, farmers from the panel of participants are supposed to put their weight in the balance, having several points to make in terms of pricing. The difficulties entailed by yam production are foremost the point to make [31]. The results show that, in spite of the probable underestimation of yam output price, Net Margins are very high compared to those of farmers' practice. This is revealing for the potential that the supply of yam tubers from treatment A can achieve if the innovation is adopted. Cost effectiveness of treatment A (wrapping of seed yam cv. Klatchi with banana-fibre paper impregnated with micro-doses of abamectin) is then grounded on the existing price differentials on yam market [19].

Overestimating prices: traders who bid a unique price are asked not to go beyond prices that are unacceptable for them. Of course, farmers can bid higher prices, while food processors and consumers can bid lower. As assumed for end-users' perceptions [2], an equilibrium view is

found. The difference in the present case, as compared to the experience of [39] with prices that were 40% and 105% over and above the cost of standard input packages, is that farmers are on the supply side, while the other end-users are on the demand side. Price of tuber from treatment A is only 10% and 16% above prices of tubers from treatments B and FP, respectively. By cross analyzing the two experiences, it appears a strikingly high difference between price ratios on both demand (input technology price) and supply (agricultural output price) sides. Most studies concluded to the low level of the premium that producers are willing to pay for input technology in the face of depressed output prices [30; 39; 43]. Therefore, it is unlikely that yam prices are overestimated, but rather underestimated as usual, and agricultural input price level stands as a driver for smallholder farmers' willingness to pay for a new farm technology [30]. For instance, the discount rate taken alone is a disincentive for adopting a new technology implying high input costs. Reference [44] suggested a tailored financial mechanism including various short, medium and long-term credits adapted to the financing of various agricultural innovations. Unless the financial service was to live up to expectations, a breakthrough could not be achieved in the adoption of new agricultural technology; these include timely credit and farming cycle adapted reimbursement [45]. Exploring constraints to agricultural innovations, reference [46] envision rural electrification as a stimulus for local initiative in favour of adoption. To the contrary of what happens in the "Failed States" [47], [48] claimed for "Regulation Theory" in line with the "Transformation of Agriculture".

This research is at the frontier of two disciplines: agronomy and social sciences. While for agronomists, the bulk of the research is in the laboratory and field works are conducted with very small samples of producers (17 farmers), social scientists conform to statistical representativeness with large sample sizes. It does not mean that one cannot reconcile both disciplines in order to achieve an interdisciplinary goal. Obviously, statistical results are assumed limited with respect to the 17 experimental farmers' fields. Nonetheless, those limits do not question the viability of the research objectives that are more exploratory than inferential.

CONCLUSION

The agricultural innovations based on "wrapping seed yam cv. Klatchi with banana-fibre paper impregnated with micro-doses of abamectin -treatment A" and "wrapping seed yam cv. Klatchi with banana-fibre paper alone -treatment B" were cost effective. Both groups of participants, researchers and farmers, were satisfied given the results achieved. What was not straightforward from the outset was that treatments A and B required around 3.78% labor more than FP. In terms of agronomic results, yield potentials of treatments A and B were very much over those of FP, as were quality criteria. Consequently, Net Margins and cost-profit ratios led to statistically significant differentials in favour of the agricultural innovations. Nonetheless, research results stand behind assumptions on the reliability of the approach based on the willingness to pay. Overestimating or underestimating yam prices could decrease or increase end-users' confidence in research goals.

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APPENDIX

Table A1: ANOVA of tuber yields for treatments A, B, and FP

Source	DF	SS	MS	F	P
Treatment	2	20,954,722	10,477,361	4.89	0.012
Error	48	102,788,650	2,141,430		
Total	50	123,743,372			

S = 1463, R-Sq = 16.93%, R-Sq(adj) = 13.47%

Source: Computed from field surveyed data, *November-December (2017)*

Source	DF	SS	MS	F	P
Treatment	2	20954722	10477361	4.89	0.012
Error	48	102788650	2141430		
Total	50	123743372			

S = 1463 R-Sq = 16.93% R-Sq(adj) = 13.47%

Source: *Données de terrain, Novembre-Décembre 2017*

Table A2: ANOVA of net margins obtained from treatments A, B, and FP

Source	DF	SS	MS	F	P
Treatment	2	1.53600E+12	7.68002E+11	13.81	0.000
Error	48	2.67017E+12	55628473242		
Total	50	4.20617E+12			

S = 235857 R-Sq = 36.52% R-Sq(adj) = 33.87%

Source: Computed from field surveyed data, *November-December (2017)*