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Cost:Benefit analysis of insect net use in cabbage in real farming conditions among smallholder farmers in Benin

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A B S T R A C T

Insect net use provides a physical exclusion of pests as well as a microclimate change, thus increasing soil humidity, vegetable quality and yields in tropical conditions. This paper presents the findings of a cost:benefit analysis of this technology in real farming conditions compared to current insecticide practices. The surveys were conducted in Benin for cabbage production (*Brassica oleracea* L.) during two production cycles. There were almost no significant differences in costs between unnetted and netted cabbage for the two production cycles. The only factors that varied were farm gate prices, the number of cabbages marketed and their size. Improved yields contributed significantly to the higher cost:benefit ratio for netting protection. Insecticide costs significantly declined by 68%–95% when shifting from unnetted protection to netted protection and total operational and labor costs declined by 3%–40%. Insect net use generated threefold higher margins and an average 1:2.66 cost:benefit ratio compared to 1:1.58 for current practices. Overall, the netting technology displayed less variation for costs, yield, and cabbage quality than insecticides. The next step is to scale up the supply of marketed insect nets.

1. Introduction

Africa has the lowest rate of pesticide use in the world but vegetable production seems to be an exception (Williamson et al., 2008). Agricultural intensification in sub-Saharan Africa is hampered by the widespread year round presence of pests. Insects are among the leading causes of harvest losses for vegetable crops (de Bon et al., 2014). For example, the major pest of cabbages such as the diamondback moth *Plutella xylostella* (Linnaeus) and the cabbage webworm *Hellula undalis* (Fabricius) are responsible for the highest yield losses in Benin (Martin et al. 2006). To ensure their production and income, farmers in Benin carry out chemical treatments more frequently with increasingly higher doses (Ahouangninou et al., 2011). They also often use unlicensed and non-recommended products with the risk of contaminating crops and the environment with poisonous residues (Ahouangninou et al., 2012; de Bon et al., 2010, 2014).

Pesticide overuse has severe environmental and health impacts. Notwithstanding soil and water contamination, chemical insecticides have been applied to such a high extent in peri-urban areas that major insect pests have developed resistance (Sarfraz et al., 2005; Carletto et al., 2010; Houndété et al., 2010). Farmers' only solution is to increase the chemical doses and spraying frequency. Insecticide overuse is facilitated by their wide availability in official or informal markets and by the lack of control or chemical residue analyses in many Sub-African countries (Ahouangninou et al., 2013). By this vicious circle, harvest losses increase, fruits and vegetables are increasingly contaminated by chemical residues, soils and groundwater are polluted, fauna destroyed and human health affected. *P. xylostella*, is an important pest of brassicaceous crops worldwide. It has developed resistance to almost every synthetic insecticide applied in the field and consequently is often hard

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to control in crucifer-growing areas (Sarfraz et al., 2005). Studies in Côte d'Ivoire, Burkina Faso and Benin showed that intensive pesticide use in the cotton cultivation *Gossypium hirsutum* L. increases the resistance of the malaria vector *Anopheles gambiae* Gilles (Yadouleton et al., 2011). This resistance thus hampers the fight against malaria, with long-lasting insecticide treated bed nets recommended by the World Health Organization.

Health impacts of pesticides are increasingly documented. Prolonged exposure to pesticides has been associated with short-term (nausea, irritation, and allergy) and long-term diseases (non-Hodgkin's lymphoma, leukemia, cardiopulmonary disorders, neurological and hematological symptoms and skin diseases) (Audibert, 2010; INSERM, 2013). From a social perspective, ill health and high healthcare costs overwhelmingly represent the greatest reason for households slipping into poverty in communities in Kenya, Uganda, India and Peru (Krishna, 2007). The health impacts of agrochemical inputs have not yet been reported as a factor contributing to the pauperization of farmers in the economic development literature, but they probably contribute to the vulnerability of farmers, along with malaria and HIV.

The World Bank supports pest control strategies that promote the use of biological or eco-friendly control methods. The European Union is conducting a program to set standards and maximum residual levels for chemicals suitable for use on agricultural products. All imports originating from non-European Union member countries must comply with these new regulatory standards (COLEACP Pesticide Initiative Programme). This is a significant challenge in Africa for present export markets as well as for domestic markets in the future. We need to anticipate future requirements in biological or eco-friendly control methods in West African domestic markets.

Integrated pest management (IPM) promotes more environmentally friendly methods for pest control, with pesticide applications as a last resort. This approach results in reduced pesticide use, increased productivity and profitability, and fewer deaths from poisoning. IPM is viewed as one of the most effective alternatives to the application of single synthetic pesticides and plant extract sprays (Pretty et al., 2011; Amoabeng et al., 2014).

IPM based on passive physical methods to protect crops is reported to be a more preventive and sustainable pest management tool (Way and van Emden, 2000). Among the various alternatives available to farmers wishing to adopt an ecological intensification approach, insect nets ensure physical exclusion of pests as well as a microclimate change, thus increasing soil humidity, vegetable quality and yields in tropical conditions (Martin et al., 2006).

Insect nets are made of synthetic or natural fiber and the netting mesh can be varied to suit the crop or the size of the target pests. The design and use of insect nets depends on the target problem they are meant to mitigate (Briassoulis et al., 2007; Martin et al., 2010, 2013). These nets are regarded as eco-friendly because they reduce pesticide use and can be recycled. The main function of insect nets is to exclude pests from the crops, but they also provide other benefits. Insect nets buffer the impact of heavy rainfall and the negative impact of several common pests such as birds and snails. Insect nets can be combined with organic fertilizers, organic mulch and drip irrigation. The suppression or reduction of chemical pesticide use reduces soil pollution. In temperate areas or in tropical highlands they stabilize the air temperature and improve soil moisture, thereby improving crop quality and yield (Muleke et al., 2013).

Insect nets were successfully tested in experimental stations and in the field with smallholder farmers in Benin, Kenya and France. Insect nets reduced insecticide sprays by 70–100% in Benin and Kenya for cabbage and tomato crops (Martin et al., 2006; Licciardi et al., 2008; Saidi et al., 2013; Muleke et al., 2013; Gogo et al., 2014; Simon et al., 2014).

This technology can (or should) be adapted to local constraints. For example, in humid climates, the netting can be occasionally removed to reduce overheating. The height of netting pegs can be adjusted depending on crop requirements. Nets of various mesh sizes are available depending on the target pests. Insect nets in orchards can also be made from hail nets. In applying this technology, the social and economic setting in which farmers conduct their activities also have to be taken into account.

Despite some limitations, cost:benefit analyses are a necessary and a preliminary step for assessing the cost-effectiveness before adoption and diffusion assessments. This paper quantifies the costs and benefits of insect nets compared to synthetic insecticide treatments in real farming conditions, i.e. considering current farmers' practices. The investigations were conducted in 4 districts of Benin.

2. Material and methods

This study is part of a larger multidisciplinary project aimed at assessing the impact of insect nets among farmers. The economic investigations involved 214 farmers, including 90 farmers who were testing insect nets. A sample of 19 farmers were randomly selected from these 90 farmers for the cost:benefit analysis. However, only 7 of these 19 farmers managed to provide us with complete data during the investigations. The 7 farmers included 2 women (farmers 2 and 6).

Even though the vegetable farmers in our sample may have been aware of official insecticide recommendations, we assessed real farming practices where recommended insecticides, doses and frequencies do not always apply. Income is farmers' first concern, so they often neglect sanitary issues. Poor insecticide practices are due to many different factors: poor access to credit for farmers, informal and uncontrolled insecticide supplies, lack of law enforcement, poor quality insecticides that may be unsuited to the targeted pests, etc. Higher insecticide doses and application frequencies could be explained by uncoordinated pest prevention among farmers, illegal use of subsidized cotton insecticides for food crop production, pest resistance and the year round presence of pests. The cost:benefit analysis estimated yields, best practice recommendations, practice diversity among farmers, total farm size, the percentage of the farm area devoted to protected and unprotected cabbage, the input type and quantity (labor, fertilizers, pesticides, fuel, motor oil) used and the depreciation components. The timing of each farming operation was recorded. The study concerning the diverse range of practices used by farmers were based on the detailed observations of the 7 farmers simultaneously operating on protected and unprotected cabbage fields.

Data were collected during two production cycles the short rainy season (October–December 2012) and the long dry season (January–March 2013) in 7 farms in the coastal region and hinterlands of Benin. Each period targeted specific holidays during which demand was high for cabbages. The long dry season targets the Easter holidays. The short rainy season targets the Christmas holidays.

The research areas were located in the coastal region and hinterlands of Benin: to the west in the districts of Grand Popo (1 farmer), Comé (2 farmers) and Ouidah (2 farmers); and to the east in the district of Sèmé-Kpodji (2 farmers). Agriculture and peri-urban agriculture in this area is characterized by intensive practices and improved access to urban markets due to the presence of the country capital (Cotonou).

2.1. Traditional farming system for cabbage production in Benin

The traditional farming system for cabbage production in Benin