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Economic feasibility of an augmentative biological control industry in Niger

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ABSTRACT

Farmers in Niger are vulnerable to high millet yield losses due to the millet head miner, *Heliocheilus albipunctella* De Joannis (Lepidoptera: Noctuidae), for which pest control options are limited. Researchers have developed a procedure to multiply and spread an augmentative biological control agent *Habrobracon hebetor* Say (Hymenoptera: Braconidae) which is effective in limiting millet yield losses due to the pest. This study assesses the economic viability of small businesses to produce and sell biological control agents. It analyzes the profitability of the businesses under alternative pricing regimes given estimated costs to produce and distribute biological control agents. The economic assessment provides budget analysis for potential businesses and discusses options for scaling, price setting, and organizing. Our study suggests that the small *H. hebetor* industry should turn a profit in Niger at relatively low prices for the biological control agents of $3.00-$4.00 per bag with 15 bags needed per village. Competitive wages are achievable for the businesses that sell to at least 13 villages. Each business would hire three workers from late May to late August. Commercialization of *H. hebetor* would generate opportunities for wide geographic distribution of the technology on a sustainable basis in Niger.

1. Introduction

Niger is among the poorest countries in the world with an annual per capita income of less than $1000 (World Bank, 2017). Agriculture accounts for 80 percent of employment and 40 percent of income (World Bank, 2013). Millet, sorghum, and cowpeas are the primary crops, with millet accounting for 70 percent of cereal production (Institut National de la Statistique, 2013). The lowest income quintile of the population spends more than 50 percent of its income on cereals, especially millet (Aker et al., 2009). Farmers in Niger rely on pearl millet as a primary source of food and income because it grows on poor soils and under moisture stress (Food and Agriculture Organization, 2016).

The most serious pest affecting millet production in Niger is the millet head miner (MHM) *Heliocheilus albipunctella* De Joannis (Lepidoptera: Noctuidae), which causes major yield losses if untreated (Gahukar et al., 1986; Nwanze and Sivakumar, 1990; Krall et al., 1995; Youm and Owusu, 1998). Farmers reported an average yield loss of 40 percent due to MHM in a recent survey (Ba et al., 2013).

Several studies have examined the life cycle and behavior of the MHM and identified its potential natural enemies (Guevremont, 1981, 1982; 1983; Gahukar et al., 1986; Bhatnagar, 1989; Gahukar, 1990; Ndoye, 1992; Youm and Gilstrap, 1993; Krall et al., 1995; Henzell et al., 1997; Youm and Owusu, 1998; Baoua et al., 2009). Infestations occur annually, and are especially severe in early-planted or maturing millet and in areas with sandy soils (Gahukar, 1987; Youm and Gilstrap, 1993; Nwanze and Sivakumar, 1990). In Niger, adult MHM moths lay their eggs on millet panicles as they emerge from early August to early September. Eggs hatch three to five days later, and larvae begin feeding on the millet panicle (Gahukar, 1989). Larval development takes about 30 days, and then the full-grown caterpillar drops to the ground and burrows to pupate (Youm and Kumar, 1995). The caterpillar remains in the ground for most of the year until it re-emerges about six weeks after the first rains, which begin in late May or June (Nwanze and Sivakumar, 1990). The millet head miner produces one generation per year.

Common pest control methods such as applying pesticides, breeding for host plant resistance, and using cultural controls have proven

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ineffective or impractical for MHM (Gahukar, 1989, 1990, 1992; Nwanze and Sivakumar 1990; Baoua et al., 2009). However, multiplication and release of the beneficial insect *Habrobracon hebetor* Say (Hymenoptera: Braconidae) has emerged as a promising control strategy. *H. hebetor* is a tiny wasp that parasitizes up to 95 percent of MHM larvae, improving yields by up to 41 percent (Ba et al., 2013; Baoua et al., 2014). The *H. hebetor* wasp stings the MHM larvae, causing paralysis and stopping metamorphosis, and then lays eggs on the larva (Youm and Gilstrap, 1993). Over 10 wasp larvae, feeding on the host, can develop in one host larva. The maturation process requires about 7 days from egg to adult (Youm and Gilstrap, 1993). Research is underway to optimize the effectiveness of *H. hebetor*'s release.

H. hebetor and the MHM are native to the African Sahel region including Niger. Until the mid-1970s, *H. hebetor* exhibited a natural parasitism of MHM of 64–95 percent and yields were minimally effected (Guevremont, 1983; Bhatnagar, 1984). However, the Sahel no longer provides a suitable environment for the beneficial parasitoids to naturally build and maintain a population large enough to mitigate millet losses to MHM (Payne et al., 2011). The natural parasitism often occurs now after the crop has been damaged (Gahukar et al., 1986; Bhatnagar, 1989; Youm and Gilstrap, 1993).

Consequently, a strategy has been developed to augment the level of *H. hebetor*'s population and release the beneficial insects at the appropriate time. Since 2006, mass releases of *H. hebetor* have been tested by the national agricultural research institutes of Niger, Mali, and Burkina Faso (Institut National de la Recherche Agronomique du Niger, INRAN; Institut de l'Economie Rural, IER, in Mali; and Institut de l'Environment et de Recherches Agricoles, INERA, in Burkina Faso). These institutions, in partnership with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Niamey, have designed effective rearing and release techniques for *H. hebetor.* ICRISAT and INRAN first undertook efforts to rear *H. hebetor* in Niger in 1998, with several experiments to refine practices to release the parasitoids (Payne et al., 2011).

A release technique using jute bags filled with millet, rice moth larvae, *Corcyra cephalonica* Stainton (Lepidoptera: Pyralidae) (food for *H. hebetor*), and impregnated *H. hebetor* was first attempted in 1999, yielding promising results (Garba, 2000). By 2000, the scientific groundwork had been laid for an effective biological control solution, but there was little institutional support to facilitate transfer of the technology to farmers (Payne et al., 2011). Since 2006, efforts have been made to: (1) implement on-farm testing of a biological control system, (2) train students, technicians, extension agents, and farmers in biocontrol techniques, (3) conduct further research on control of the head miner; and (4) evaluate pearl millet varieties for resistance to the head miner (Payne et al., 2011).

Based on research and testing results, Ba et al. (2014) lists the current best practices for on-farm *H. hebetor* releases. The technique involves placing two mated-female *H. hebetor* in a 7 cm × 10 cm jute bag filled with 200 g of millet grain, 100 g of millet flour, and 25 rice moth larvae (*C. cephalonica*). A set of 15 jute bags are placed around a village's farms, with three bags placed on a centrally-located farm and three bags placed on farms in each cardinal direction (N, S, E, W) from the central farm. Typical villages have a diameter of 1 km, and bags can be placed up to 500 m from the central farm although most are placed within 100–200 m. Bags can be suspended from the ceilings of straw granaries, or if straw granaries are not available, they can be protected against wind and rain and hung from trees or wooden stakes. Parasitoids reproduce and multiply within bags, and their offspring escape through the jute mesh and disperse. A new generation emerges after 7–14 days, with the average development time around 12 days. One bag generates 57–71 parasitoids (Ba et al., 2014). If 15 bags are utilized, approximately 1000 parasitoids are released within 12 days, and the population can build to over a million within four weeks. *H. hebetor* can travel up to 5 km from release point and parasitize 90% of MHM larvae under this procedure, resulting in a yield increase of 34% (Baoua et al., 2014).

Unfortunately, INRAN and ICRISAT lack the capacity to annually breed and distribute *H. hebetor* to farmers on a large scale. Augmentative biocontrol is often a commercial endeavor (Van Lenteren, 2012). It has been applied on more than 30 million ha worldwide, and approximately 350 species of natural enemies are commercially available (Van Lenteren et al., 2017). The largest demand is in greenhouse crops in Europe and the United States. Africa accounts for only about two percent of the market for commercial augmentative biological control agents (Cock et al., 2010).

Establishing a small private *H. hebetor* industry in Niger may be feasible due to the minimal capital investment and labor required to raise the insects. Maintaining the source of insects requires little effort for most of the year and full-time work for only two months to mass multiply and distribute the insects. The technology is effective, and many farmers indicate that they would be willing to purchase bags of *H. hebetor* (Ba et al., 2013). Commercialization of the *H. hebetor* would generate opportunities for wide geographic distribution of the technology on a sustainable basis.

Private production and distribution may make the beneficial insects widely available to farmers, but public research institutions can play a role in initiating the process due to the nature of the market and the technology. The market consists of subsistence farmers living in scattered, sometimes isolated, rural areas. Millet fields typically surround small villages, although occasionally individual farm-households are separate from village centers, especially if they possess several livestock. The technology, while not complicated, does require training of the businesses to multiply the insects, time the insect distribution to farmers, set initial prices, and determine the geographic scope of their market.

Testing of the technology followed by village focus-group discussions revealed that commercialization of the biological control technology may encounter a "free rider" problem in that *H. hebetor* in open fields will spread up to five km from its release point (Baoua et al., 2014; Ba et al., 2014). Because all farmers within that radius of release benefit from the parasitoids' activity, farmers could have an incentive to wait for their neighbors to buy the beneficial insects so that they can receive the benefits without incurring the cost. Free riding could potentially make it difficult for businesses producing the beneficial insects to sell sufficient quantities to cover costs.

The primary objective of this study is to assess the economic feasibility of establishing a beneficial-parasitoid industry despite the potential free-riding problem. The study documents expected costs and returns of businesses created to produce and distribute *H. hebetor.* It also briefly discusses the possibility of cooperative arrangements for purchasing the beneficial insects at the village level to minimize free riding. Such arrangements might take advantage of existing farmer federation networks in Niger that provide farmer groups with inputs, financial services, and technical assistance. The study describes potential risks to the businesses and considers the appropriate size of businesses given economies of size and other parasitoid distribution issues.

2. Materials and methods

A list of expenditures to multiply and distribute *H. hebetor* to villages were obtained from laboratories currently involved in *H. hebetor* research and multiplication and from pilot testing the insect multiplication and distribution process with six small "businesses" which were set up for that purpose. Cooperative purchasing arrangements through existing farmer federations were examined that would provide positive net benefits for each participant farmer while excluding non-participants from receiving the same benefits.

Nigerian farmer federations may play an important role in the distribution of *H. hebetor* because they already provide benefits to farmer participants through access to agricultural inputs, financial services,

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