THE ROLE AND SIGNIFICANCE OF FARMER PARTICIPATION IN BIOCONTROL-BASED IPM FOR BRASSICA CROPS IN EAST AFRICA

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ABSTRACT

Few attempts on biological control of arthropod pests on annual crops in sub-Saharan Africa have been successful. This is because of (1) inadequate taxonomic information on potential biocontrol agent(s), target pest and preferred host plants; (2) insufficient adaptation of potential agent(s) to bio-ecological conditions; (3) lack of consideration of the total pest complex of the target crop and farming systems; and (4) poor involvement of farming communities and extension personnel in information dissemination. The ICIPE-led diamondback moth (DBM) biocontrol project for East and Southern Africa has been addressing these issues since its inception in 2000.

*Diadegma semiclausum*, an exotic DBM parasitoid, was released in Ilkiding’a-Arusha/Tanzania pilot area in October 2002. Hands-on farmer training was conducted before the release. The establishment, spread and impact of the parasitoid was monitored through surveys. Parasitism rates increased from 10% before release to 36.2% and 66% (10 months and two years after release, respectively). Farmers reduced spraying frequency and changed increasingly to Bt-based products, many stopped spraying for DBM control completely. Aphid control measures changed from area to spot application. In consequence, DBM population and damage was significantly reduced. Evidence from neighbouring areas, where the parasitoid had spread to but where farmers were not trained, indicated that farmers were unaware about the presence of the parasitoid. They continued routine spraying with broad-spectrum insecticides. Consequently, the level of parasitism was much lower and damage very high.

The lessons from this experience and their implications for wider use are discussed in this presentation.

INTRODUCTION

cabbage, *B. campestris* L. var. *pekinensis/chinensis* and broccoli, *B. oleracea* L. var. *italica*, are among the major crucifer vegetables grown for home consumption and for cash in many parts of East Africa, notably in the highlands. They are a valuable source of vitamins and minerals. About 90% of the crop is produced by small holders on \( \frac{1}{4} \) to one-acre land holdings. The bulk of the produce is sold in urban centers where it has high demand as a relish.

In East Africa, crucifers are grown in a wide range of agro-ecological conditions, and therefore, the pest complex and intensity, and management strategies practiced by farmers vary within and between farmers and locations.

A wide range of pests (insects and diseases) attacks the crop (Varela *et al.* 2003). The diamondback moth, *Plutella xylostella* (L.), aphids, *Brevicoryne brassicae* L., *Lipaphis erysimi* (Kaltenbach) and *Myzus persicae* (Sulzer), the webworm, *Crocidolomia binotalis* Zeller, the sawfly, *Athalia* sp. and cutworms, *Agrotis* spp, are the major insect pests. Although DBM was identified as the key pest of brassica crops in Eastern and Southern Africa in a workshop conducted in 1995 (Nyambo and Pekke 1995), the pest status of the cabbage aphid, *B. brassicae*, is becoming increasingly a major threat to brassica crops in East Africa. Its attack is associated with the transmission of the tulip mosaic virus (TuMV) disease, which can be devastating to the crop. Black rot, *Xanthomonas campestris* pv *campestris* (Pammell) Dawson, downy mildew, *Peronospora parasitica* (Pers.) Fr., and the tulip mosaic virus, TuMV, are the key diseases limiting production. Thus, any pest control strategy recommended to growers must consider its implications to the total pest complex within the prevailing production system. In East Africa, mixed cropping is common and pesticides recommended for one crop are used on a number of crops in the production system (Macharia *et al.*, 2005; Nyambo, pers. obs.).

Until recently, application of synthetic pesticides was the preferred method of controlling pests of crucifers in East Africa, and testing of pesticides remained the major research activity (Löhr *et al.* 1998). In Kenya, the tests conducted in 1995/96 showed that organophosphates, carbamates and pyrethroids were no longer giving effective control of DBM compared to new products such as growth regulators, phenyl pyrazole and Bt-aizawai-based products (Kibata 1996). More recent studies confirmed that Karate, the most commonly used insecticide, is not only ineffective against the DBM; its use had negative economic returns in four separate trials (Macharia *et al.* 2005). There has also been an increase in complaints from farmers and extension workers about the loss of effectiveness by the majority of commonly used insecticides against crucifer pests, particularly the DBM, in Kenya and Tanzania in recent years (Macharia *et al.* 2005).

Due to the existing pest complex in crucifer crops and the status of DBM as indicated above, effective pest control approaches that emphasize integrated pest management at farmer level, are imperative in the East African production systems. Thus, recent studies have emphasized biocontrol-based IPM for crucifer crops in the region. The main objective has been to identify and develop IPM compatible components that can be used by the majority of the small-scale farmers in the region and a delivery vehicle that can ensure sustainable uptake. This involved a two-pronged approach (1) development of biocontrol-based IPM approaches and (2) participatory dissemination of new knowledge generated.
DEVELOPMENT OF BIOCONTROL-BASED IPM APPROACHES IN EAST AFRICA BIOCONTROL OF DIAMONDBACK MOTH

Since it was becoming increasingly difficult to control DBM with the commonly used synthetic pesticides, it became necessary to investigate use of natural enemies, a practice successfully used in Asia. The identification of suitable DBM natural enemies for integration in pest management strategies for East Africa has been a process that started with (1) inventory of indigenous natural enemies (2) assessment of the effectiveness of local natural enemies, (3) proper taxonomic studies though molecular techniques of local natural enemies, and (4) search for more effective natural enemies for introduction into the region.

EFFECT OF INDIGENOUS NATURAL ENEMIES ON DBM

In surveys conducted in Kenya, Tanzania, and Uganda in 2000/2001, parasitism rates were shown to be below 15% (Löhr and Kfir 2002). In this study, the most frequent parasitoids were *Diadegma mollipla* (Holmgren) (Hymenoptera: Ichneumonidae) and *Oomyzus sokolowskii* (Kurdjumov) (Hymenoptera: Eulophidae). Entomopathogens, notably *Zoophthora* sp., *granulosis* virus (PlxyGV) and an unidentified bacterial diseases were also recorded in Kenya and Tanzania but their impact on DBM was well below 2% (Cherry et al. 2004; Nyambo pers. obs.; Oduor et al. 1997).

PROBLEMS OF PROMOTING BIOLOGICAL CONTROL OF DBM IN EAST AFRICA

**Taxonomic confusion.** Before publication of the review of Diadegma parasitoids of diamondback moth (Azidah et al. 2000), all Diadegma spp collected from DBM in African countries were considered as *D. semiclausum* and/or simply *Diadegma* spp. Biocontrol practitioners challenged this as *D. semiclausum* has been successfully used for the control of DBM in Asia (Amend and Basedow 1997; Singh et al. 1993; Talekar et al. 1989) and there was no obvious reason why it should not perform in the East African highlands where conditions are very similar. Azidah et al. (2000) grouped all African Diadegma parasitoids of DBM under *D. mollipla*. This was confirmed by Wagner et al. (2002), using molecular taxonomy techniques in the ICIPE led DBM project. Henceforth, the indigenous *Diadegma* spp attacking DBM in East and Southern Africa is now commonly known as *D. mollipla* (Wagner et al. 2002), a parasitoid that is more effective on the potato tuber moth, *Phthorimaea opercuella* (Zeller). This scientific revelation on the true taxonomic status of the African Diadegma species provided the justification to import and introduce *D. semiclausum* from Asia to the East Africa highlands. The parasitoid was introduced to Kenya, Tanzania and Uganda following the existing national biocontrol regulations all of which are based on the FAO code of conduct.

**Insufficient adaptation of potential agent(s) to bio-ecological conditions.** Ecological adaptation and efficiency of biotypes is yet another constraint that had to be addressed to ensure optimization of identified agents. Some populations of *Cotesia plutellae* are recognized as efficient control agents for DBM, while others are very poor (Amend and Basedow 1997; Talekar, pers. comm.). The *C. plutellae* biotype of South Africa is a highly efficient parasitoid as compared to the very rare ecological homologue *Apanteles* sp. (misnamed *C. plutellae*) in East Africa (Löhr and Kfir 2002). Therefore, the South Africa strain was chosen for mass rearing and introduction in semi-arid areas of East Africa.
Lack of consideration of the total pest complex of the target crop and farming systems. There have been few successful attempts to control arthropod pests of annual crops using biocontrol agents. This is partly due to the fact that perennial crops offer a more stable environment where both the pest and its natural enemy can co-exist for a long time. In annual crops, success has been achieved in systems where continuous cropping and harvesting is practiced, e.g. the cassava mealybug (Neuenschwander 2003; Nyambo pers. obs.) and/or where alternative host plants provides refugia for the pest and its natural enemy. This could be the real reason for the success of the cereal stem borer biocontrol programme in Eastern and Southern Africa and the successful suppression of bean fly maggot in some parts of Ethiopia by Opius phaseoli Fischer and Sphegigaster bruneicornis Ferrière (Abate 1995; Nyambo pers. obs.).

The single pest approach, which ignores other important and/or potential pests, and is adopted in many situations, has contributed to the failure of many other biocontrol attempts (Abate 1995). This is because farmers will continue to apply pesticides to control the other major crop pests for which no alternative control measures are known. This not only threatens the survival and effectiveness of biocontrol agents, but also brings into question the rationality of attempting biocontrol on a single pest within a crop pest complex (Nyambo 1995). The attempted biological control of the potato tuber moth, Phthorimaea operculella Zell in Zambia 1979-82 using two introduced parasitoids, Copidosoma koehleri Blanchard and Bracon greeni Ashmead failed in some areas because farmers continued to apply broad spectrum insecticides to control aphids and the spread of viral disease in the crop. However, where farmers stopped spraying, the parasitoids were well established and brought the pest under control (Mingochi et al. 1995). The same fate applied to the attempt to control Helicoverpa armigera Hübner in tomato, eggplants, okra and tobacco in 1980 using Trichogrammaidea armigera Nagaraja and Apanteles ruficrus Haliday (Mingochi et al. 1995). This must have happened because farmers were neither informed nor knowledgeable about their role in enhancing effective biocontrol of arthropod pests. A single method approach to pest control will also not be efficient and sufficient for the brassica production systems of East Africa due to the existing pest complex. Based on this background, it became necessary to investigate the possibility of combining biocontrol with other compatible options that will facilitate optimization of introduced biocontrol agents.

Lack of biocontrol compatible alternatives. The situation reported in Zambia (Mingochi et al. 1995) is not unique and could be repeated in many other production systems if not well addressed. To optimize the benefits of the biocontrol-based IPM programme in East Africa, it was deliberately planned in the ICIPE led DBM project to investigate and integrate all possible strategies that would reduce over-dependency on synthetic pesticides.

BOTANICAL PESTICIDES

In recent years, many farmers in East Africa started to use plant extracts, often home extractions from a wide range of plants, for pest control in a wide range of crops. This has partly been because synthetic pesticides are costly, and, as indicated above, they are ineffective in controlling key pests. However, not all plant extracts are compatible with biocontrol agents. Some could also have negative effects on non-target organisms, human and the environment,
and this has to be avoided. Fortunately, the use of neem-based pesticides has been greatly researched worldwide including at ICIPE (Schmutterer and Ascher 1984; 1987), and commercial formulations are available in local shops.

The use of botanicals to control major insect pests of crucifers and their compatibility with arthropod natural enemies was studied in Kenya (Akol et al. 2002; 2003; Okoth 1998) and South Africa (Charleston et al. 2003). In the work done in East Africa, extracts from the neem tree, *Azadirachta indica* A. Juss, were found effective against the DBM and had low negative effects on *D. mollipa*, the indigenous DBM parasitoid, and therefore, could be used as alternatives to synthetic pesticides where they are available. Neem-based pesticides were also tested elsewhere and found to be compatible with arthropod natural enemies of DBM (Haseeb et al. 2004; Leeson 2001). As a result, neem-based products are being promoted as alternatives to the commonly used synthetic pesticides among crucifer growers in the region.

**BIOPESTICIDES**

Microbial control agents with potential against DBM have been recorded in East Africa as indicated above. However, their contribution in regulating DBM populations is low. Some of these, e.g. the granulosis virus, PxlyGV, is a potential agent that could be produced, formulated and applied (Cherry et al. 2004; Grzywacz et al. 2002). Dudutech, a private company based in Kenya, has taken up this challenge and the work is on going. Moreover, some strains of *Bacillus thuringiensis* (Bt) have been shown to give effective control of DBM and other lepidopteran pests, and, with low negative effects on potential arthropod natural enemies of DBM (Amend and Basedow 1997; Haseeb et al. 2004; Kibata 1996; Kok and Acosta-Martinez 2001; Krishnamoorthy 2002; Ng et al. 2002). Based on these findings, Bt-based products, such as dipel, thuricide, xenthari, all available from local pesticide dealers, are suggested as an option where spraying lepidopteran pests becomes necessary.

**AGRONOMIC PRACTICES**

This is the basis for sound IPM development and promotion (Varela et al. 2003). It encompasses selection of varieties with some tolerance to key pest problems when and where available, e.g. the Danish types of cabbages are known to be tolerant to mosaic virus. Use of certified disease free seeds are highly recommended as a strategy for controlling black rot. Mulching the crop with dry grass in the nursery and field has been shown to (1) minimize attack by aphids and therefore the build up of tulip mosaic viruses (Achieng et al. 2003) (2) provide attractive environment for ground dwelling natural enemies and (3) conserve ground moisture for better plant growth, and (4) reduces splash and hence early black rot infestation. Other measures include plant nutrition, water management, e.g. when and how to use overhead or furrow irrigation, field sanitation and time of planting, proper selection and application of pesticides based on frequent (at least once a week) crop scouting and making use of the observations for decision making.

Many growers still have to spray against the cabbage aphid, and so guidance on which insecticide to choose and how to spray for effective control of aphids have to be made clear to the end users. The current best practice is spot application on infested plants only. This has given satisfactory results in smallholder cabbage production.
PARTICIPATORY DISSEMINATION OF RESEARCH OUTPUTS

Good research results are useful if they are properly disseminated to end-users. Many biological control attempts in sub-Saharan Africa ignored the role and contribution of national extension services and farmers, which contributed to failures and lack of sustainability (Mingochi et al. 1995; Nyambo 1995). The ICIPE-led DBM project attempted to address this issue by involving and engaging the national research and extension programme of the collaborating countries in project formulation (Nyambo and Pekke 1995; Seif and Löhr 1998), research and dissemination of results. Workers of the national research and extension departments in each respective country conducted the surveys on indigenous natural enemies. National programmes largely handled parasitoid release and monitoring activities (Fig. 1).

DISSEMINATION OF THE RESEARCH OUTPUTS TO FARMERS

To ensure sustainable uptake and dissemination to farmers, it was deemed necessary to capacitate the national extension workers in each respective country (Fig. 1). This was done through an intensive one-week hands-on training course in biocontrol-based IPM for master trainers in each collaborating country. The course targeted the district subject matter specialists (horticulture and crop protection). These course participants would be responsible for down streaming the information through their national extension systems until it reaches the farmers. The national biocontrol units were given a two-week training course on how to rear the natural enemies and carry out field releases. The two national units were to collaborate in terms of planning effective field releases in major crucifer growing areas.

CASE STUDY: ILKIDING’A, ARUMERU DISTRICT, TANZANIA

The multi-practice approach was field tested at Ilkiding’a, Arumeru District Tanzania in October 2002, a coffee-vegetable based production system. Two of the master trainers from the Tanzanian Ministry of Agriculture and Food Security (MAFS) identified the release site in an area where cabbage growing is taking off as a cash crop among small-scale farmers. Baseline data were collected for a year before the planned field releases. The level of parasitism in northern Tanzania was about 10% before releases. Farmers were already spraying twice a week from transplanting to harvest using either selecron, endosulfan, decis or karate (alone or in mixtures), all recommended for use on coffee, and yet the cabbage produce was of extremely poor quality. The DBM pressure on the cabbage crop in the area was causing a crisis situation. This being a highland area, *D. semiclausum* was the preferred agent. A release permit was obtained from the Plant Health Service, MAFS. On the day of the release, a hands-on farmer training was conducted. It involved a demonstration of the parasitoid and a question and answer session to educate the farmers about *D. semiclausum* (what it is, how it works) and the role of farmers in its preservation. About 20 farmers and the village extension worker from the locality participated in the training. Farmers were shown how to release the agents and participated actively in the release exercise. Approximately 700 female and a similar number of male parasitoids were released. Thereafter, the farmers were left alone. It was anticipated that the agent would get established and propagate itself in the area while the know-how would be spread by word of mouth between farmers. The event was captured on the local TV and radio stations and broadcast during the week of field release.
RESULTS

Ten months after first releases, the level of DBM parasitism had increased to 36.2%, this increasing to 66% after two years at the release site (Fig. 2). At the release site, farmers reduced spraying frequency and changed increasingly to Bt-based products and many stopped spraying for DBM control completely. Aphid control measures changed from area to spot application. In consequence, DBM population and damage was significantly reduced from 32 DBM/plant pre-release period to 4.0 DBM/plant in two years. This is a very significant improvement considering the fact that spraying has been reduced to a maximum of two per season and the crop quality improved. Evidence from neighbouring areas, where the parasitoid had spread to but farmers were not trained, indicated that farmers were unaware about the presence of the parasitoid. They continued routine spraying with broad-spectrum insecticides. Consequently, the level of parasitism was much lower, with an average of 51% and 1.8 damage score per plant (Fig. 2).

Following these results, a refresher course for the Tanzania master trainers was organized in collaboration with Ilkiding’’a farmers. The Ilkiding’’a cabbage growing area became a classroom for the extension workers and the course facilitators in February 2005.
LESSONS FROM THE ILKINDING’A RELEASE SITE

1. Participatory research and extension, that emphasizes production systems and pest complex, should be the way forward to enhance and facilitate sustainable uptake and effectiveness of identified arthropod biocontrol agents.

2. Capacitating farmers to take active participation in biological control initiatives is of utmost importance to ensure successful establishment of the agent, its propagation and effective control of target pest.

3. Field releases of biocontrol agents and farmer training has to be planned in such a way that they occur simultaneously.
   a. I see I remember
   b. I touch I remember
   c. I hear, I see, I touch, I remember more

   It is important to emphasize to farmers the fact that, unlike pesticide sprays, which give results within a short time, biocontrol takes time and the results may not be immediate. The Ilkiding’a group realized the effects of the agent in the September-October 2003 cabbage crop, a year after the first release. To them, this was the real convincing point, which marked the start of the success of the initiative. They learned by doing it themselves.

4. Farmer training should be supported with other forms of ICT to reinforce the message and also to raise awareness among other growers in similar growing zones. It should not be a one-off activity.
   a. Although *D. semiclaustrum* spread to over 10 km from the release point in two years, the knowledge about it and how to enhance its effectiveness remained concentrated...
at the release point (Fig. 2). As a result, crucifer growers in other villages continued to use the broad-spectrum pesticides and damage on the crop persisted despite the presence of the parasitoid.

b. The radio and TV programmes were a motivation to the farmers at the release point to practice what they learned. It also served to raise some awareness at the district level, and as a result, other growers made some enquiries wanting to learn from the farmers at Ilkiding’a.

c. The TOT course participants need to visit successful release sites to learn from growers for them to conceptualize and internalize the value of biocontrol-based IPM practice.

CONCLUSIONS AND THE WAY FORWARD

Thoroughly researched and carefully implemented classical biological control is an important tool for integrated pest management. Equally important are the consideration of the whole pest complex of the crop and the participation of farmers and extensionists in research and implementation. This ensures full understanding of the introduced changes and allows the natural control factors to play their role. The ICIPE-led DBM biocontrol-based IPM for brassica crops could become a role model for other biocontrol attempts in Africa.

REFERENCES


Amend, J., and Basedow, T. H. 1997. Combining release/establishment of Diadegma semiclausum (Hellen) (Hym., Ichneumonidae) and Bacillus thuringiensis Brl. For control of Plutella xylostella (L.) (Lep., Yponomeutidae) and other lepidopteran pests in the Cordillera Region of Luzon (Philippines). *Journal of Applied Entomology* 121, 337-342.


