Can Vetiver Grass be Used to Manage Insect Pests on Crops?

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Abstract: Apart from its well known soil conservation properties, vetiver grass (*Chrysopogon zizanioides* (L.) Roberty; syn. *Vetiveria zizanioides* (L.) Nash) is reported to be repellent to many insect species. However, infestation of vetiver by pests of other crops has been recorded and concerns raised about vetiver grass being a refuge for insects pests. This paper addresses the benefits that vetiver may have in control of these pests. *Chilo partellus*, a lepidopterous stem borer of grasses is a pest that is often mentioned in vetiver literature. This insect is a serious pest of maize, rice and other grain crops in Asia and throughout East and Southern Africa where it can cause total crop failure. These observations prompted research on insect/vetiver grass interactions to determine the response of stem borer moths and larvae when they encounter *Vetiveria zizanioides* plants. The response of moths to vetiver grass, which could be either positive (attraction or arrestment) or negative (repulsion), would determine if vetiver grass could be used as trap crop for *C. partellus* in an integrated pest management system. Wild grasses such as Napier grass (*Pennisetum purpureum*) is successfully used in habitat management systems in East and Southern Africa. Studies were therefore conducted to determine preference of female moths for vetiver grass compared to maize and to determine the suitability of vetiver, Napier grass and maize for survival of stem borer larvae. Two-choice preference bioassays and larval survival experiments were conducted. Results indicated that vetiver grass was highly preferred for oviposition but that larval survival on vetiver grass was extremely low. Thus, vetiver has potential as trap crop component of an overall "push-pull" strategy to concentrate *C. partellus* oviposition away from the maize crop and reduce subsequent population development. This technology may also have application in rice pest management.

Key words: agro-ecosystems, *Chilo partellus*, habitat management, insect pests, maize, rice, *Oryza*, stemborers

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1 INTRODUCTION

Much anecdotal evidence exist that vetiver grass (*Chrysopogon zizanioides* (L.) Roberty; syn. *Vetiveria zizanioides* (L.) Nash) is repellent to insects. Grimshaw and Helfer (1995) reported that after 30 years of working with vetiver grass no pest or disease problem was found that was of practical or economic importance to the farmer. However, concerns regarding the status of vetiver grass as host or refuge to insect pests and diseases of other crops have been raised by the National Research Council (1993) and Dafforn (1996; 2000). Vetiver grass technology is used globally as soil erosion management tool and in sustaining agricultural productivity (Grimshaw, 2003). Vetiver grass technology, in its most common form, is the establishment of a narrow (less that 1 m wide) live stiff grass barrier, in the form of a hedge across the slope of the land (Grimshaw, 2003). Apart from its use as insect repellent and soil erosion management tool, vetiver grass has numerous traditional uses such as root paste for headaches and leaf paste for rheumatism and sprains (Rao and Suseela, 2000). Commercial uses of vetiver grass mainly pertain to the extraction of vetiver oil through distillation of the roots. Vetiver oil has extensive applications in the soap and cosmetic industries and is also used as anti-microbial and anti-fungal agent in the pharmaceutical industry (Rao and Suseela, 2000).

Stem borers and termites seem to be the most commonly reported pests of vetiver grass. Paddy stem borers (*Chilo* spp.) have been reported to infest culms and midribs of leaves wherever vetiver grass was planted in Southern China. An interesting observation was that although the levels of mortality amongst stem borer larvae were high no pupae were ever found inside plants. In the worst case, the borer damaged approximately 39 % of grass stems but no pupae were found (Xinbao, 1992), indicating that no larvae survived in the plants. Zisong (1991) in China reported that stem borers attacked a vetiver grass hedge planted in a tea plantation and that on average of 1.5 to 6 % of individual tillers was killed.

Shangwen (1999) reported a stem borer (Lepidoptera: Pyralidae) to occur in vetiver stems. Although this was most probably a *Chilo* sp., he did not provide further information on its identification. An interesting observation made by Shangwen (1999) was that population densities of many of the herbivorous insects on vetiver was low and that they did not do any apparent damage to plants. In El Salvador vetiver grass has been reported to be an alternative host plant to the cane borer, which is a pest of maize and sugar cane. However, although moths were reported to lay their eggs on vetiver grass, plants were not affected by borer larvae (Anonymous, 1997). If stem borer preference for vetiver grass is high, which seems to be suggested by these observations, the possibility exists that this plant could be used as a trap plant around crops on which stem borers are a problem. This technique of using wild grasses as trap crops for stem borers is used effectively in Africa in a push-pull strategy where Napier grass (*Pennisetum purpureum*) is used to concentrate oviposition away from maize crops and to reduce subsequent population development (Khan *et al*., 1997, Khan *et al*., 2000, Van den Berg *et al*., 2001).

This paper provides an overview of insect pests of vetiver grass and presents data on the preference of *C. partellus* moths for vetiver grass and survival of stem borer larvae on this plant species. The possible role of vetiver in pest management is discussed and compared with that of Napier grass, which is already used successfully to manage stem borers.

2 MATERIALS AND METHODS

Two-choice experiments were conducted in the laboratory and greenhouse to determine oviposition preference response of *C. partellus* moths when presented with a choice between vetiver grass and maize. Larval survival was determined in one of these bioassays. An additional experiment was conducted to determine larval survival on vetiver grass and Napier grass.

2.1 Laboratory bioassay

The experiment was conducted in muslin cloth cages (45 x 52 x 82 cm) and was replicated three times using potted plants. One pot contained an actively growing vetiver plant and the other contained a four week old maize plant. Two-day old moths were collected from oviposition cages in a mass rearing facility. Ten female and ten male moths released into the centre of each cage and allowed to oviposit overnight. The number of eggs on each plant was determined.

2.2 Green house bioassay

This experiment was conducted to determine moth oviposition preference and subsequent larval survival on vetiver and maize plants growing in the soil in a commercial green house.

Two rows of maize were planted on one side of a row of established vetiver grass while one row was planted on the other side. The inter-row spacing was 0.5 m. The vetiver grass row was one year old and had dense stand of tillers. Six muslin cloth cages (3.0 x 1.5 m x 1.5 m) were placed transversely over the three rows of maize and one row of vetiver grass when the maize plants were five weeks old. Each cage formed a replicate and enclosed within it was 14 maize plants and a 1.3 m long row of vetiver grass.

Twenty male and twenty female moths were released in each cage and allowed to oviposit on plants for two nights. The number of eggs on maize plants was determined by carefully inspecting the foliage of each plant. One half of the vetiver row in each cage was removed from the soil in order to inspect each leaf for eggs. Leaves were removed from slips and checked for eggs. An assumption was made that the numbers of eggs on the remaining half row in the cage was similar to that in the part of the row that was removed from the soil.

In order to determine larval survival, maize plants and the remaining one-half of the vetiver row in each cage was left to grow normally. Twenty-eight days after egg hatch, all the maize plants and the remaining half of the vetiver row were removed from the soil and the number of surviving larvae determined. This was done by dissecting stems and leaves. It takes approximately 30 days for *C. partellus* to complete its life cycle on maize. Percentage larval survival was calculated in terms of the number of eggs that was found on maize plants and the vetiver plants that were removed from cages.

2.3 Larval survival on vetiver and Napier grass

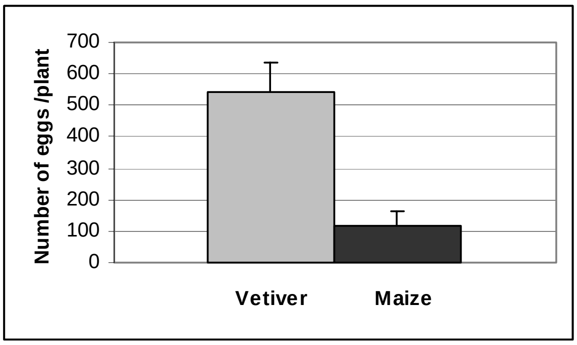
Larval survival was compared among maize, Napier and vetiver grass in a screen house using potted plants. This was done to compare larval survival on vetiver grass with Napier grass, which is currently used in habitat management for control of stem borers of maize (Khan et al., 2000; Van den Berg et al., 2001). This experiment was replicated five times with two plants of each of maize, vetiver and Napier in each replicate. Plants were infested with a known number of eggs and dissected 28 later to recover larvae.

3 RESULTS

3.1 Laboratory bioassay

Results indicated that *C. partellus* moths preferred to lay eggs on vetiver grass as compared to maize (Fig. 1). Of the total number of eggs, only 18 % were laid on maize. Vetiver plants received an average of 544 eggs each while maize plants received only 119 eggs.

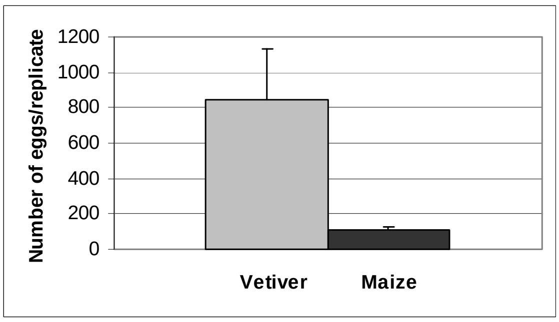
Fig. 1. Mean number of eggs per plant laid by *Chilo partellus* moths in two-choice tests with maize and vetiver plants under laboratory conditions (Bars indicate Standard Error).



3.2 Green house bioassay

In the green house where plants were grown under more natural conditions than in pots, by far the majority of eggs were laid on vetiver grass (Fig. 2). Significantly more eggs were laid on vetiver grass from which a total of 5094 eggs were recovered compared to the 684 from maize. This indicated that only 13.4% of the total number of eggs was laid on maize. The total number of maize plants in each replicate received an average of two egg batches while an average of 49 egg batches were laid on each vetiver row. A clear preference for vetiver grass compared to maize was therefore shown.

Fig. 2. Mean number of eggs per replicate laid by *Chilo partellus* moths on plants in two-choice tests under green house conditions (Bars indicate Standard Error).

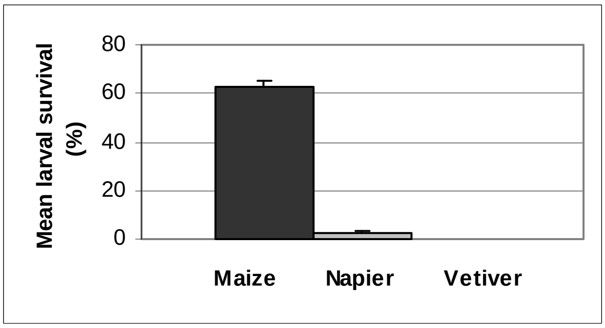


Results indicated that more larvae were recovered from maize than the number of eggs actually laid on plants. The number of larvae recovered from maize plants in the green house was 132% and that on vetiver grass 0.56%. The high numbers on maize can be ascribed to the nonpreference of larvae for vetiver and subsequent emigration of larvae from these plants to maize. The total number of larvae that could have been recovered from maize and vetiver in the experiment, if 100% of larvae survived emigration off vetiver to maize, would have been 5778, but a total of only 986 larvae were recovered. This indicated that in spite of having a suitable host plant (maize) next to the vetiver plants, larval mortality was still very high with 83% of possible larvae not accounted for at the end of the experiment.

3.3 Larval survival on vetiver and Napier grass

Larval survival on grasses was low compared to that of maize. On average there was 63.0%, 2.8% and 0% larval survival on maize, Napier and vetiver grass respectively (Fig. 3), a distinct show of 100% mortality of larvae on vetiver grass. These results corroborate those of the studies above with an indication that *C. partellus* prefers vetiver grass for oviposition with subsequent insignificant rates of larval survival.

Fig. 3. Percentage survival of *Chilo partellus* larvae on maize, vetiver and Napier grass, 28 days after egg hatch (Bar indicates Standard error).



4 DISCUSSION

Results showed that *C. partellus* moths preferred to lay eggs on vetiver grass compared to maize. Larval survival on vetiver plants was low, indicating high levels of larval spin-off and mortality on this plant.

This behaviour of *C. partellus* moths to lay eggs on host plants that are not suitable for feeding and development of their offspring have been reported for other crops. Van den Berg and Van der Westhuizen (1997) reported that *C. partellus* moth preference for sorghum varieties with high levels of antibiosis was high. Observations made by Shangwen (1999), Xinbao (1992) and Zisong (1991) on high numbers of infested vetiver plants but low or zero larval recovery from plants do in fact show that it is not suitable as larval host pant in spite of it being attractive for egg laying.

This principle of attractiveness for egg laying but low larval survival observed on certain grasses was exploited in the development of habitat management systems for stem borers in maize in Africa. The identification of alternative trap crops that could be used in cropping systems with maize, sorghum and rice, where stem borers are economically important pests, would be a significant contribution towards sustainable crop production. The strong attraction of vetiver grass for *C. partellus* moths makes this grass species an option as a trap crop in cropping systems where *C. partellus* is a pest.

Chilo partellus is from the Old World tropics, from where it dispersed to East and Southern Africa during the early twentieth century (Maes, 1998) to become a serious pest of maize and sorghum. Similarly, vetiver grass originated in South Asia where India was most probably the primary centre from where it dispersed to other areas (Lavania, 2000). The strong preference of *C. partellus* for vetiver grass could possibly be ascribed to an old association of this insect with this plant during the period before its current primary host plants (maize, sorghum and rice) were domesticated.

Although it has not yet been evaluated the possibility exists that *C. partellus* moths may also prefer vetiver grass to other crops such as rice (*Oryza sativa*). If this is the case vetiver grass could be used as trap crop around paddy rice fields where it is used as field boundaries and as a soil conservation measure to protect rice from flood damage during the rainy season (Huq, 2000). Many *Chilo* spp., including the notorious *C. partellus*, are pests of graminaceous crops such as maize and rice in Asia and East and Southern Africa (Seshu Reddy, 1990) (Table1). The Napier grass push-pull technology used in Africa could serve as a model for vetiver grass in ecosystems where it is already used on a large scale or where Napier grass technology is not applicable.

It has been reported that technologies such as vetiver grass or Napier grass as soil conservation measure will only be adopted significantly if there are added benefits to the technology other than a single benefit such as soil erosion protection. Forage value of the grass may also play a role in adoption of the technology (National Research Council, 1993). This has been the case in East Africa where a high rate of adoption of Napier grass push-pull technology against stem borers in maize has been reported (Khan *et al*., 2000).

Vetiver grass technology is already applied in countries where stem borers are important pests of maize. In Costa Rica, vetiver grass is used principally as conservation hedge for the protection of maize, beans, coffee and tobacco (Rojas, 1997). Similarly, vetiver grass technology was introduced and adopted by many farmers in East and Southern African countries such as Malawi, Zambia, Zimbabwe, Tanzania and South Africa (National Research Council, 1993). Carr (2000) in Malawi reported that vetiver technology was used by small scale farmers in 290 major water catchment areas and that vetiver nurseries were established in 2038 villages in the country. From these nurseries approximately 20 000 farmers have planted vetiver grass on their farms. Part of the technology to manage stem borers therefore already exists on thousands of farms. This technology would have an even greater impact and possibly an even higher adoption rate if it could also be marketed as trap crop for stem borers. This benefit would however only realise if the correct spatial arrangement of the vetiver grass trap crop is used, and the target stem borer species, *C. partellus*, is present.

Table 1. *Chilo* species, their hosts and distribution (Source: Seshu Reddy, 1990).

Chilo spp.	Host plants	Distribution
C. agamemnon Bleszynski	Maize, rice, sorghum,	Israel, Egypt, Sudan, Uganda
C. aleniella (Strand)	Rice	West Africa, Uganda
C. auricilius Dudgeon	Sugar-cane, rice, Sorghum	South-east Asia
C. christophi Bleszynski	Rice	China, Japan, USSR

C. diffusilineus (J de Joannis)	Rice, maize sorghum, pearl millet	W. Africa, Ethiopia, Sudan, Tanzania, Malawi, Mozambique, Zimbabwe
C. hyrax Bleszynski	Rice	China, Japan, USSR
C. indicus Kapur	Sugarcane	India
C. infuscatellus Snellen	Sugarcane, sorghum, maize, rice, Italian millet	India, Afghanistan, Pakistan, Korea, Thailand, Philippines, China, USSR, Indonesia, Timor, South Vietnam
C. luniferalis (Hampson)	rice	W. Africa, Ethiopia, Sudan
C. luteellus (Motschulsky)	maize, rice	North Africa, Near East, Central Asia, China, Korea, Japan, Philippines, Spain, Italy, Rumania
C. mesoplagalis (Hampson)	rice	West Africa, Sudan
C. orichalcociliellus Strand	maize, sorghum	Kenya, Tanzania, South Africa, Congo, Madagascar
C. panici Wang & Sung	*Panicum miliaceum*	China
C. partellus (Swinhoe)	Maize, sorghum, rice, pearl millet, finger millet, wheat, sugarcane	Eastern and Southern Africa, Indian sub-continent
C. perfusalis (Hampson)	Rice	West Africa
C. phragmitellus (Hubner)	Rice	Japan
C. plejadellus Zincken	Rice	USA, Canada
C. polychrysus (Meyrick)	Rice	India, Bangladesh, Thailand, Malaysia
C. psammathis (Hampson)	Rice	West Africa
C. sacchariphagus (Bojer)	Sugarcane, sorghum	Mauritius, Madagascar, Re-Union, Indonesia, Malaysia, Philippines, China, Taiwan
C. sacchariphagus indicus Kapur	Sugarcane	India and Sri Lanka
C. sacchariphagus stramineelus (Caradza)	Sugarcane	China, Japan, Taiwan
C. supermain	Rice	Iran
C. suppressalis (Walker)	Rice, maize, sorghum	East Africa, India, Pakistan, Japan, Vietnam, China, Korea, Philippines, Spain, Australia
C. terrenellus Pagenstecher	Sugarcane	Papua New Guinea, Australia
C. tumidicostalis (Hampson)	Sugarcane	India, Nepal
C. zacconius Bleszynski	Rice, sugarcane	West Africa

4.1 Grasses as refugia for pests

Although wild host plants of stem borers play an important role in the carry-over of pest populations from one season to another, the destruction thereof may not be as advantageous as reported in earlier studies (Ingram, 1958; Seshu Reddy, 1985). Destruction of wild host plants of stem borers has been advocated by many researchers (Seshu Reddy, 1985; Van den Berg *et al*., 1998). Timely burning of vetiver grass was also recommended to rid it from pests (National Research Council, 1993).

However, as was already mentioned, wild host plants play an important role in the ecology of stem borers, and the fact that they harbor pests, may actually be beneficial to the farmer (Khan *et al*. 1997, Van den Berg *et al*., 2001, Ndemah *et al*., 2002). Using selected grasses of economic importance in an integrated technology for stem borer management is the way towards sustainable pest management since these grasses can provide natural control of stem borers.

It has been established that several wild grasses, such as Napier grass, commonly growing near farmers' fields in tropical Africa provide important refugia for stem borers natural enemies such as *Cotesia flavipes* (Hymenoptera: Braconidae) and *Cotesia sesamiae* (Hymenoptera: Braconidae), after the cereal crops are harvested. Some species of borers, such as *Bactra stagnicolana*, *Phragmataecia boisduvalii* and *Poeonoma* sp., associated with these perennial wild hosts can be important hosts for *Cotesia* spp. and other natural enemies of crop pests. These host plants can therefore be very important in the ecology of natural enemies (ICIPE, 1996; Van den Berg *et al*., 1998).

No extensive study has been conducted on the insects that occur in vetiver grass refugia. Personal observations show that many insect species occur on this grass. It can be said this plant species provides shelter, not only to a few potential insect pests, but also to a large number of general predators and parasitoids of insects that occur in the agro-ecosystems where vetiver grass is planted.

In the only study of its type, Shangwen (1999; 2001) recorded 102 insect species that occurred on vetiver plants during two seasons of vetiver production in China. Among these he distinguished 13 species as leaf eaters, four as sucking insects and 19 as herbivores on spikes, stems and roots of plants. Many of these species could be identified as general herbivores (such as grass hoppers). Sixty four percent of the insect species observed on vetiver was identified as visitors or natural enemies of other insects. These observations showed that insect biodiversity in vetiver could actually be high.

Several pests of vetiver have been recorded. The most notable of these were stem borers (*Chilo* sp.) white grubs, termites and cicadas (Table 2). In the Mekong delta in South Vietnam patches of dead vetiver on a canal bank adjacent to rice fields were ascribed to stem borers, possibly a *Chilo* sp. (P. Truong, personal communication). Very high infestation levels of the cicada, *Amphisalta zelandica*, were reported on vetiver in New Zealand where they affected plant growth (Miller, 2003). Another vetiver species, *V. nigritana*, have been reported to harbour large numbers of egg pods of two grasshopper species, *Hieroglyphus daganensis* and *Cataloipus fuscocoeruleipes* (Shah *et al*., 2000). Both these grasshopper species are major pests of sorghum, rice and millet in northern Benin. Armyworms, *Spodoptera* sp., are also reported to damage vetiver in Australia (P. Truong, personal communication). However, this damage does not seem to be of economical importance since only the tips of vetiver leaves were damaged while the rest of the plants were untouched. Field observations indicated that sugar cane plantings adjacent to vetiver plantings were severely damaged, indicating that armyworms possibly preferred sugar cane to vetiver.

4.2 Vetiver grass as insect repellent

Anecdotal evidence exist that vetiver roots *per se* is repellent to insects. Vetiver roots for example are used to repel cloth moths, head lice and bed bugs. Scientific reports do however exist of repellent compounds present in vetiver oil extracted from roots of vetiver grass. Vetiver oil is a complex essential oil that consists of several hundreds of compounds (Zhu *et al*., 2001) of which six are reported to possess insect repellent properties (Jain *et al*., 1982). The latter authors, in bioassays with vetiver oil, found it to have topical irritant activity on cockroaches and flies. Further testing resulted in the identification of zizanal and epizizanal as the most active repellent compounds against these insects. The scientific names of these insects were however not mentioned in any of the reports. Zhu *et al*. (2001) indicated that one of the components of vetiver roots, nootkatone, was a strong repellent and toxicant to Formosan subterranean termites (*Coptotermes formosanus* (Isoptera: Rhinotermitidae)) and suggested planting of a barrier of plants that manufacture a termite repellent could potentially provide repellence to this pest.

4.4 Napier grass, vetiver grass technology and soil erosion

Expanding agricultural production in rain fed areas in Africa has been accompanied by a substantial increase in soil erosion. Increasingly, conventional approaches to soil and moisture conservation such as bunding, check dams and terracing, which are both cost and labour intensive, is inappropriate to marginal farms. Alternative low-cost approaches are needed to control soil erosion (Davies, 2000).

While the major agricultural application of vetiver grass is soil erosion control, the major application of Napier grass is forage production. These two plant species should not be seen as “either/or” options but rather as two similar technologies of which the application is largely affected by environmental conditions and adaptations thereto, as well as specific constraints to sustainable farming (such as pests, forage availability and soil erosion). There are many similarities in characteristics and possible uses of these two plant species. Added-on benefits of vetiver grass technology is its use as insect repellent, its use in manufacture of building material, its slight use as animal feed and its possible use as a trap crop for *C. partellus*. The added-on benefits of Napier grass, apart from its role as trap crop, are soil erosion management, large-scale use as forage and subsequent increased milk production as well as protection of crops against wind damage.

Although there is little published literature a few studies identified a number of grasses as being worthy of investigation regarding its efficacy in prevention of soil erosion (National Research Council, 1993). These included Lemon grass (*Cymbopogon citratus*), several *Vetiveria* spp. and Napier grass. Research in India showed that vetiver grass technology reduced rainfall run off by 57% and soil loss by over 80% (Rao *et al*., 1991). Owino and Gretzmacher (2002), in a study on vetiver grass and Napier grass in Kenya, observed that Napier grass was more effective in reducing run off and soil sediment loss than vetiver grass. Napier grass reduced run off by 40 and 70% in two subsequent years while soil sediment loss was reduced by 88 and 96% in the same years. Contradicting reports on competition of vetiver grass and Napier grass with the bordering crop have been published. Most evidence seem however to suggest that competition between crop and hedgerow is reduced or absent at high rain fall conditions (Tschering *et al*., 1995; Hensel, 1997; Dalton and Truong, 1999).

Table 2: Insect pests and other potentially damaging herbivorous insects reported on vetiver

Insect species or group	Plant part	Source
Termitidae	roots	Nat. Res. Council 93
Stem borers	leaves	Zisong (1991)
White grub (*Eupladia* ?)	roots	Nat. Res. Council 93
Phyllophaga serrata	roots	Nat. Res. Council 93
Holotrichia serrata	roots	Grimshaw &Helfer 95
Armyworm	leaves	Xinbao (1992)
Paddy borer (*Chilo* sp.)	stem	Xinbao (1992)
Leaf cutter ants	leaves	Anon. (1997)
Amphisalta zelandica (Hemiptera: Cicadidae)	roots	Miller (2003)
Oxya intricata (Orthoptera: Acrididae)	leaves	Shangwen (1999)
Atractimorpha burri (Orthoptera: Acrididae)	leaves	Shangwen (1999)
Catantops rufipennis (Orthoptera: Acrididae)	leaves	Shangwen (1999)
Aulacophora cattigarensis (Coleoptera: Chrysomelidae)	leaves	Shangwen (1999)
Aulacaphora femoralis (Coleoptera: Chrysomelidae)	leaves	Shangwen (1999)
Tussock moths (Lepidoptera: Lymantridae)	leaves	Shangwen (1999)
Callitettix versicolor (Homoptera: Cercopidae)	leaves	Shangwen (1999)
Nephotettix cincitceps (Homoptera: Cicadellidae)	leaves	Shangwen (1999)
Neodartus sp. (Homoptera: Cicadellidae)	leaves	Shangwen (1999)
Aphididae (Homoptera: Aphididae)	leaves	Shangwen (1999)
Icerya purchasi (Homoptera: Margarodidae)	leaves	Shangwen (1999)
Ceroplastes rubens (Homoptera: Coccidae)	leaves	Shangwen (1999)
Mealy bugs (Homoptera: Pseudococcidae)	leaves	Shangwen (1999)
Xyleborus sp. (Coleoptera: Scolytidae) ??	stem	Shangwen (2001)
Saccharicoccus sp. (Homoptera: Pseudococcidae)	stem	Shangwen (2001)
Aclerda sp. (Hemiptera: Acleridae)	stem	Muniappan (2001)
Aulacaspis madiunensis (Hemiptera: Diaspididae)	stem	Muniappan (2001)
Chlorophorus annularis (Coleoptera: Cerambycidae)	leaves	Shangwen (2001)
Cylas formicaries (Coleoptera: Apionidae)	leaves	Shangwen (2001)
Tesseratoma papiosa (Hemiptera)	leaves	Shangwen (2001)

5 CONCLUSIONS

An increased understanding of the influence of plant- and associated arthropod-species diversity on pest populations will lead to the development of recommendations for utilizing grasses such as vetiver and Napier grass and their associated arthropod-diversity resources for pest management.

There are many similarities between the vetiver grass technologies as it is used for soil erosion management and Napier grass push-pull technology which is used for stem borer control. Vetiver grass has potential as trap crop component of an overall "push-pull" strategy to concentrate *C. partellus* oviposition away from the maize crop and reduce subsequent population development. Future studies should evaluate the effect of vetiver grass on other *Chilo* species to determine whether this plant species could be of use as trap crop in rice cropping systems.

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A brief introduction to the first author

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