

This article was downloaded by: [ZR Khan]

On: 31 May 2012, At: 01:18

Publisher: Taylor & Francis

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



International Journal of Pest Management

Publication details, including instructions for authors and subscription information:
<http://www.tandfonline.com/loi/ttprm20>

Farmers' knowledge and perceptions of blister beetles, *Hycleus* spp. (Coleoptera: Meloidae), as pest herbivores of *Desmodium* legumes in western Kenya

Lefulesele N. Lebesa^{a b c}, Zeyaur R. Khan^a, Kerstin Krüger^b, Toby J.A. Bruce^d, Ahmed Hassanali^e & John A. Pickett^d

^a International Centre of Insect Physiology and Ecology, P.O. Box 30772, Nairobi, 00100, Kenya

^b Department of Zoology and Entomology, University of Pretoria, Private Bag X20, Pretoria, 0028, South Africa

^c Department of Agricultural Research, Box 829, Maseru, 100, Lesotho

^d Biological Chemistry Department, Rothamsted Research, Hertfordshire AL5 2JQ, Harpenden, UK

^e Chemistry Department, Kenyatta University, P.O. Box 43844-00100, Nairobi, Kenya

Available online: 21 May 2012

To cite this article: Lefulesele N. Lebesa, Zeyaur R. Khan, Kerstin Krüger, Toby J.A. Bruce, Ahmed Hassanali & John A. Pickett (2012): Farmers' knowledge and perceptions of blister beetles, *Hycleus* spp. (Coleoptera: Meloidae), as pest herbivores of *Desmodium* legumes in western Kenya, *International Journal of Pest Management*, 58:2, 165-174

To link to this article: <http://dx.doi.org/10.1080/09670874.2012.673032>

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: <http://www.tandfonline.com/page/terms-and-conditions>

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae, and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand, or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

Farmers' knowledge and perceptions of blister beetles, *Hycleus* spp. (Coleoptera: Meloidae), as pest herbivores of *Desmodium* legumes in western Kenya

Lefulesele N. Lebesa^{a,b,c,*}, Zeyaur R. Khan^a, Kerstin Krüger^b, Toby J.A. Bruce^d, Ahmed Hassanali^e and John A. Pickett^d

^aInternational Centre of Insect Physiology and Ecology, P.O. Box 30772, Nairobi 00100, Kenya; ^bDepartment of Zoology and Entomology, University of Pretoria, Private Bag X20, Pretoria, 0028, South Africa; ^cDepartment of Agricultural Research, Box 829, Maseru, 100, Lesotho; ^dBiological Chemistry Department, Rothamsted Research, Harpenden, Hertfordshire AL5 2JQ, UK; ^eChemistry Department, Kenyatta University, P.O. Box 43844-00100, Nairobi, Kenya

(Received 11 January 2011; final version received 18 October 2011)

A survey was undertaken to determine the pest status of herbivorous blister beetles, *Hycleus* spp., in western Kenya where they attack crops such as *Desmodium* spp., other leguminous plants and sweetpotato. *Desmodium* spp. are important intercrops in the 'push-pull' strategy adopted for *Striga* and stemborer control in maize and sorghum. Production of desmodium seed is adversely affected by blister beetles, which feed on the flowers and negatively affect seed setting. To assess farmers' knowledge and perceptions of *Hycleus* spp. as pests, a questionnaire survey was conducted in three sites in Bungoma district, western Kenya, in 2007. The survey was followed by field sampling of *Desmodium* spp. and sweetpotato to compare the results with the responses received from farmers. *Hycleus* spp. were mentioned by 75% of the respondents as major pests of *Desmodium* spp. During field sampling *Hycleus* spp. comprised 70% of the insect pests collected. According to farmers, blister beetles were more abundant on desmodium than on sweetpotato. However, field sampling revealed that differences in beetle abundance on the two crops were not consistent across different sites, suggesting that these crops may function as alternative hosts. The study provides baseline information for the development of a management strategy for blister beetles.

Keywords: *Desmodium* spp.; questionnaire; field survey; pest status; sweetpotato

1. Introduction

Desmodium spp. (Fabaceae), such as *Desmodium uncinatum* Jacq. DC., play an important role as intercrops for maize and sorghum in "push-pull" crop protection strategies due to their repellent ("push") properties against maize stemborers (Lepidoptera), and their ability to cause suicidal germination of dormant seeds of witchweed, *Striga* spp. (Scrophulariaceae), and so suppress population levels of that parasitic weed (Khan et al. 2000, 2002, 2006a, 2006b, 2008a). The "push-pull" strategy was developed for small-scale farmers by ICIPE (International Centre of Insect Physiology and Ecology) and its two partners, KARI (Kenya Agricultural Research Institute, Kenya) and Rothamsted Research, UK (Pickett 1998; Cook et al. 2007; Khan et al. 2008a). Apart from its role as an intercrop in the "push-pull" technology, *Desmodium* spp. (hereafter referred to as desmodium) are also nutritious fodder crops for livestock (PANESA/ARNAB 1990; Paterson et al. 1998; Khan et al. 2006a). Thus, desmodium is valuable for small-scale farmers. The increased demand for desmodium seed associated with the widespread adoption of the "push-pull" technology prompted ICIPE and its partners to

establish community-based desmodium seed production units in East Africa (Khan et al. 2008b).

The main constraint upon the production of desmodium seed is infestation by blister beetles, notably *Hycleus* spp. (Coleoptera: Meloidae; formerly *Coryna*) (Pickett et al. 2010; Lebesa et al. 2011), which feed on flowers causing damage and preventing the development of seed. Apart from desmodium, blister beetles have been observed feeding on floral parts of other crops such as sweetpotato, cowpea and okra in several parts of western Kenya (L.N. Lebesa, unpublished observations). The available literature on meloids in Kenya, however, mainly documents *Coryna* and *Mylabris* as being associated with other leguminous crops (Abate and Ampofo 1996; Hillocks et al. 2000). *Mylabris* spp. and *Coryna* spp. are reported to co-occur frequently on the same plant crop in various sub-Saharan countries (Abate and Ampofo 1996; Tanzubil and Yakubu 1997; Lale and Sastawa 2000). In West Africa, several species of blister beetle, for example *Psalydolytta* spp., *Mylabris* spp. and *Hycleus* spp. (formerly *Coryna*) (Bologna and Pinto 2002), have been observed feeding on pollen or flowers of various grain crops such as sorghum, pearl millet and cowpea,

*Corresponding author. Email: lefulesele@yahoo.com

which reduces grain yields (Gahukar 1991; Lale and Sastawa 2000).

Adult blister beetles may range from 5 mm to 40 mm in body length, depending on the species (Scholtz and Holm 1986). The adult female lays cylindrical eggs in batches in the soil. Upon hatching into active larvae called triungulins, the progeny search for grasshopper eggs for feeding (Hill 1975; Selander 1986; Abate and Ampofo 1996; Özbek and Szaloki 1998). The larvae develop into later larval stages inside the grasshopper egg pod (Nikbakhtzadeh 2004). Damage to plants is inflicted by adult beetles only; these feed on both floral parts as well as on the developing seeds, thereby negatively affecting seed setting and, consequently, yields. Meloids are largely polyphagous, feeding on a wide range of host plants within families such as Fabaceae, Malvaceae, Convolvulaceae and Solanaceae (Selander 1986; Bologna and Pinto 2002; Zhu et al. 2005; Lebesa et al. 2011).

Although the presence of blister beetles in different crops is usually not considered to be a serious constraint (Hill 1975; Zhu et al. 2005), infestations of crops grown in small-holder plots may cause considerable damage because of the gregarious nature of adult blister beetles (Hall 1984; Nikbakhtzadeh 2004). Evans et al. (1989) reported that more than 80% of flowers and developing pods of a prairie legume, *Baptisia australis* (L.) R. Br. (Fabaceae) were damaged by the blister beetle *Epicauta fabricii* LeConte, thereby adversely affecting seed production. Blister beetles are similarly becoming a very important pest in East Africa because of increasing demand for desmodium seeds by small-holder farmers adopting the “push–pull” strategy for controlling stemborers and striga. As an introduced crop in eastern Africa (Agnew and Agnew 1994; Cook et al. 2005), there is limited information on its pests, especially blister beetles, which represent a significant challenge to desmodium seed production and the “push–pull” farming system.

We undertook a survey to provide baseline information required for the development of management strategies for blister beetles on desmodium. A questionnaire was provided to small-holder farmers to: (i) assess their knowledge and perception of the pest status of blister beetles (*Hycleus* spp.), (ii) document current control methods and their effectiveness, and (iii) record the farmers’ perceptions of the host range of the blister

beetles. In addition, a field survey to assess the abundance of blister beetles on desmodium and alternative host plants was undertaken to compare the results with the responses of farmers.

2. Material and methods

2.1. Household survey

A household survey was undertaken in the Bungoma district (0°34' to 0°39'S, 34°30' to 34°32'E) in the Western Province in Kenya in October and November 2007 to identify potential crops infested by blister beetles; this was followed by a field survey. A questionnaire was developed and enumerators with knowledge of the local language were trained on how to interview farmers. Thereafter, enumerators undertook face-to-face interviews in 92 farm households. Participating farmers were selected randomly within the three categories of farmers from three sub-locations in the Bungoma district. Of these, 44 were from Marakuru and Tutii and involved in producing desmodium seed, 33 farmers from the same areas were practising the “push–pull” technology, and 15 farmers from Kapchai were not involved in either the “push–pull” technology or desmodium seed production. The latter group of farmers was, however, planting sweetpotato (*Ipomoea batatas* (L.) Lam., Convolvulaceae), an alternative host of *Hycleus* spp. (Table 1). Care was taken to balance gender, where possible, to avoid a potential sex bias.

The questionnaire was prepared to obtain information on: (i) demographic information on farmers, which included gender and the highest education level attained; (ii) farming practices, including farm sizes, type of crops planted, and mode of farming (mono- or mixed-cropping); and (iii) farmers’ perception of pest problems on desmodium and other crops (pest status, extent of damage caused by blister beetles, control methods used, if any) to compare this with previously received reports from desmodium seed producers.

To improve accuracy of information gathering, the questionnaire included colour pictures of the different blister beetle species (Figure 1). If farmers were able to identify one or more species, they were asked to provide further information on the blister beetles. This included: (i) their abundance during different times of the day and seasons, (ii) the species that were dominant, (iii) the parts of the plant that were observed to be damaged, and (iv) estimated loss due to blister

Table 1. Study sites, geographical zones and farmers’ sample distribution.

| Sub-location | Elevation (m a.s.l.) | Coordinates | No. of farmers per farm type | | | Total no. of farmers |
|--------------|-------------------------|------------------------------|------------------------------|--------------------|-----------------|-------------------------|
| | | | Push–pull technology | Seed production | No desmodium | |
| Marakuru | 1430–1530 | 0°38'–0°40'N, 34°31'–34°32'E | 13 | 18 | – | 31 |
| Tutii | 1230–1540 | 0°35'–0°39'N, 34°30'–34°33'E | 20 | 26 | – | 46 |
| Kapchai | 1390–1490 | 0°35'–0°36'N, 34°31'–34°32'E | – | – | 15 | 15 |

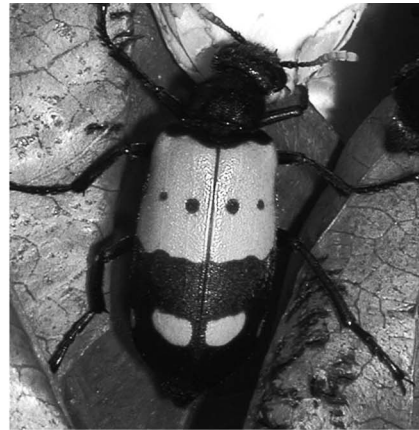
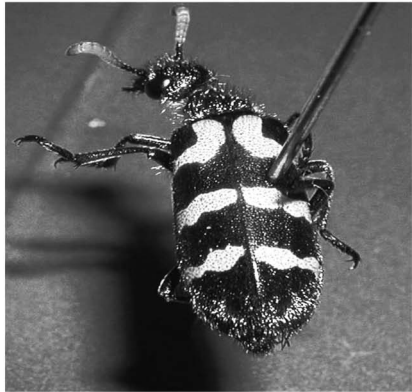
*H. apicicornis**H. dubiosus**H. vestitus**H. sjoestedti**H. vestitus**H. distinctus*

Figure 1. *Hycleus* spp. recorded on *Desmodium* spp. and sweetpotato in different parts of Kenya between 2006 and 2009. These sample pictures were shown to farmers in Bungoma to identify which of the beetles attacked their crops (identification of beetles by Marco Bologna, Roma TRE University).

beetle attack compared to years when damage by beetles was minimized through pesticide application. Farmers' responses were divided into "yes" or "no" categories (e.g. recognition of blister beetles), or into three- to five-point codes representing a response to each question (e.g. pest recognized and mentioned by a farmer had five-point codes).

2.2. Field sampling

Although farmers mentioned desmodium, sweetpotato and beans (*Phaseolus vulgaris* (L.), Fabaceae) as the

main host crops of *Hycleus* spp. in Bungoma, only desmodium and sweetpotato had reached flowering stages and therefore were available for sampling. Sampling for the presence of blister beetles and other pests was undertaken in the sub-locations of Marakuru, Tutii and East Bukusu (another desmodium-producing area) in the Bungoma district, western Kenya. East Bukusu replaced Kapchai, because the latter had neither sweetpotato nor desmodium plants at the time of the survey.

Sampling was done twice in the space of two weeks (week 43 in October and 46 in November 2007) to

capitalize on availability of flowers. During the first sampling, three fields of each crop were sampled except for Marakaru where only two sweetpotato fields were available. Desmodium, on the other hand, was sampled only from Tutii and Marakaru because in East Bukusu, desmodium plants had been slashed off and only sweetpotato could be sampled. *Hycleus* spp. have two peak activity periods which occur in the morning between 09:00h and 11:00h and in the afternoon between 15:00h and 17:00h (L. N. Lebesa, unpublished data). Accordingly, sampling of blister beetles on the two crops was undertaken during these peak activity periods. Separate records were kept for the morning and afternoon periods. During the second sampling period, two fields per crop (desmodium and sweetpotato) were sampled.

During each survey, sampling was carried out in a standard area of 100 m² within each field because of variations in field size. Because desmodium and sweetpotato plants are creepers, it was difficult to distinguish between individual plants. Therefore, twenty 1 × 1 m sub-plots within a field were chosen at a spacing of 2 m and sampling followed a W-pattern across the field. Leaves and flowers present within the 1 × 1 m sub-plots were visually inspected for the presence of beetles and other pests.

Since blister beetles tend to drop to the ground and feign death when disturbed, aerial parts of plants were lifted to search the ground underneath for the beetles. Beetles were collected and kept in aerated containers that were labelled with the field number and location, host plant, date and time of sampling for inspection in the laboratory to separate species and sex.

2.3. Statistical analysis

Calculation of the percentage of farmers giving the same response to a question was based on the total number of farmers that responded to the question. If a farmer gave more than one answer to a question, each was included in the appropriate group of responses to the question. As a result, percentages for some questions exceeded 100% (Ebenebe et al. 2001; Tefera 2004; Obopile et al. 2008). Chi-squared analyses of the relevant frequencies were analysed as 2 × 2 contingency tables to determine whether the beetle abundances were related to the two practices of growing desmodium (“push–pull” technology or seed production) and to the number of years that a farmer had been involved with desmodium production. Gamma correlation was further used to determine correlations between years of experience of growing desmodium and the pest status of blister beetles (Healey 1990).

Data from the field sampling were not normally distributed even after transformation, therefore non-parametric tests were employed for analyses. Kruskal–Wallis analysis of variance (ANOVA) was used to

determine the significance of differences in the abundances of beetles between different fields, and within and between the host plants sampled in each location. Paired tests were used to test for any significant differences between the abundances of beetles on the two hosts at two sub-locations (Mann–Whitney U-test) and their abundances in the morning compared to the afternoon (Wilcoxon Matched Pairs test). Data were analysed with Statistica (Version 7.0, StatSoft, Inc., 1984–2004).

3. Results

3.1. Household surveys

3.1.1. Demographic characteristics and production practices

The overall male to female ratio for all interviewed farmers was approximately 1 : 1, with slightly more females (53%) than males (47%). The overall proportion of females and males interviewed was similar for desmodium farmers (49% males and 51% females), although at Kapchai (a non-desmodium growing location) more female (67%) than male (33%) farmers were interviewed. The majority of the interviewed farmers had formal education, 42% having attended primary and 50% having attended secondary school. Only 8% had no formal education (Table 2).

Table 2. Summary of socio-economic characteristics and production practices of farmers interviewed.

| Variable | Marakaru <i>n</i> (%) | Tutii <i>n</i> (%) | Kapchai <i>n</i> (%) | Total responses <i>n</i> (%) |
|---|--------------------------|-----------------------|-------------------------|------------------------------------|
| <i>Gender</i> | | | | |
| Female | 16 (52) | 22 (48) | 10 (67) | 48 (53) |
| Male | 15 (48) | 24 (52) | 5 (33) | 44 (47) |
| <i>Education</i> | | | | |
| No formal education | 5 (16) | 1 (2) | 1 (6) | 7 (8) |
| Primary (Std 1–8) | 7 (23) | 25 (54) | 7 (47) | 39 (42) |
| Secondary (Form 1–4) | 19 (61) | 20 (44) | 7 (47) | 46 (50) |
| <i>No. of crops per field</i> | | | | |
| 4–5 | 6 (19) | 9 (19) | 2 (13) | 17 (18) |
| 6–7 | 16 (52) | 27 (59) | 11 (74) | 54 (59) |
| >7 | 9 (29) | 10 (22) | 2 (13) | 21 (23) |
| <i>Desmodium farm size (ha)</i> | | | | |
| *NA | – | – | 15 (16) | 15 (16) |
| <0.40 | 17 (55) | 32 (70) | – | 49 (53) |
| 0.40–0.80 (1–2) | 11 (35) | 13 (28) | – | 25 (27) |
| 0.81–2.02 (2–5) | 3 (10) | 1 (2) | – | 4 (4) |
| <i>Years of experience with desmodium</i> | | | | |
| 1 | 2 (7) | 3 (7) | – | 5 (7) |
| 2 | 12 (39) | 12 (26) | – | 24 (31) |
| 3 | 9 (29) | 14 (29) | – | 23 (30) |
| >3 | 8 (26) | 17 (37) | – | 25 (32) |

*Refers to those farmers that were not growing desmodium.

Farms were characterized by small-holdings, ranging from less than 0.4 ha to approximately 2 ha per farm. On average, farmers' plots were 0.4–0.8 ha per crop, including desmodium. The majority of the farmers (80%) grew five or more crops, most of which were intercropped (Table 2). The only two crops that were almost exclusively monocropped were sweetpotato (99%) and cowpea (92%). Maize and beans were the most important crops, grown by 100% and 98% of farmers, respectively. Desmodium was grown by 84% of farmers who either practised the “push–pull” technology (39%) or were involved in seed multiplication (52%), while 9% were involved in both practices. Other crops grown included cassava (*Manihot esculenta* Crantz, Euphorbiaceae), bananas (*Musa acuminata* Colla, Musaceae), coffee (*Coffea arabica* L., Rubiaceae), groundnuts (*Apios americana* Medik., Fabaceae) and Napier grass (*Pennisetum purpureum* Schumacher, Poaceae).

The majority of farmers (62%) growing desmodium had been exposed to the crop for 3 years or more. Farmers with three or more years of experience tended to be seed-bulking farmers (39%). Other than for “push–pull” and seed bulking, a small percentage of farmers (3%) grew desmodium for fodder production. Two desmodium species, silverleaf (*Desmodium uncinatum*) and greenleaf (*D. intortum*), were almost equally planted by farmers. Forty-seven per cent and 51% of farmers mentioned *D. uncinatum* and *D. intortum*, respectively, while 2% were growing both.

3.1.2. Farmers' perception of pest incidence on different crops

The pests mentioned by farmers for crops other than desmodium were stemborers (Lepidoptera); African bollworm, *Helicoverpa armigera* (Lepidoptera); aphids

(Hemiptera: Aphididae); blister beetles, *Hycleus* spp.; sweetpotato weevils (Coleoptera: Curculionidae) and mole-rats (Bathyergidae), depending on the crop. For desmodium, only two pests, namely *Hycleus* spp. and *H. armigera*, were mentioned, of which the latter was not considered a serious pest of desmodium and was mentioned by less than 10% of farmers who grew desmodium (Figure 2).

3.1.3. Knowledge of blister beetles, their host plants and damage caused

Of the 92 farmers interviewed, the highest number of them reported blister beetles as pests of desmodium (63%) and beans (58%), followed by sweetpotato (51%). Only a few farmers mentioned blister beetles as pests of maize (14%) and cowpea (3%) (Figure 2). Seventeen per cent of the farmers believed that *Desmodium* spp. were free of pests. Farmers reported damage by blister beetles on flowers, seeds, leaves, and stems of crops attacked. For all crops, farmers reported the highest damage on flowers of beans (73%), desmodium (60%), sweetpotato (92%), and cowpea (100%), as well as pollen feeding on maize tassels (53%). For desmodium, damage to seed pods was considered most common after damage to flowers and was mentioned by 45% of desmodium-growing farmers. Damage to leaves and stems was mentioned by 14% and 3% of the desmodium farmers, respectively.

When the pictures of different species of blister beetle were presented to farmers, 86 of them (93%) were able to identify the insects they were familiar with. The three species that were recognized were *Hycleus apicicornis* (72%), *H. dubiosus* Marseul (43%) and *H. sjostedti* Borchmann (40%). Farmers mentioned that all three species were observed feeding on desmodium,

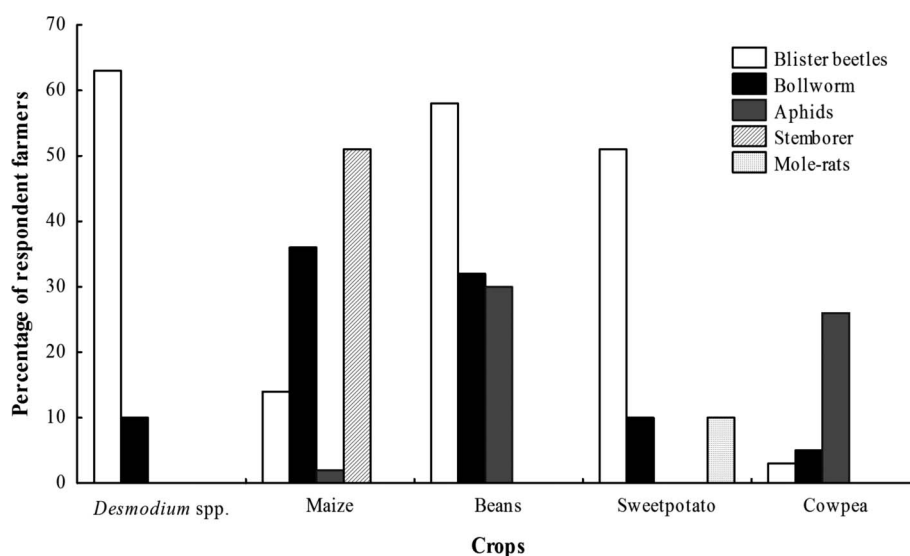


Figure 2. Percentage of respondent farmers that mentioned various pests that attack different crops in Bungoma.

maize, sweetpotato and beans, while on cowpea, farmers noted only *H. apicicornis* (Figure 3).

Farmers were able to specify the time of peak activity of the blister beetles during the day and different seasons of the year. Seventy-two per cent of farmers mentioned the long rainy season (May–July) as the period when blister beetles were most abundant. Sixty-seven per cent and 79% of the farmers mentioned 06:00–08:00h and 17:00–19:00h, respectively, as the hours at which activity of beetles peaked during the day.

The incidence of blister beetles reported by farmers at the two locations was compared. The percentage of farmers who mentioned the presence of blister beetles on *Desmodium* spp. was higher in Tutii (82%) than in Marakaru (62%); however, differences in the number of farmers reporting blister beetles on *Desmodium* spp. in the two sub-locations were not significant ($\chi^2 = 3.42$, $df = 1$, $P = 0.064$). There was a significant positive correlation between the experience farmers had in growing desmodium and the reported pest status of blister beetles on desmodium ($\gamma = -0.35$, $n = 77$, $P = 0.015$).

3.1.4. Current control methods used against blister beetles

Although blister beetles were recorded by the majority of farmers as a pest on the three major crops (beans, desmodium, and sweetpotato), only a few farmers were using control measures against the beetles. For desmodium, 33% of farmers were using some control measures, while for all other crops this was below 10%.

The three control measures mentioned were chemical pesticides, physical methods (hand-picking of beetles and crushing) and application of ash. Of these, application of chemical pesticides was the most common, mentioned by 75% of farmers who were applying some form of control. Reasons given by farmers who did not employ any form of control measures against blister beetles included lack of knowledge on what to use (72%), unaffordable cost of pesticides (21%) and low pest damage (5%).

Although the majority of farmers with blister beetle problems (82%) were not using any form of control, they rated it as a serious pest on both desmodium and beans. The severity of blister beetle damage on beans was said to be higher in mixed cropping systems (81%) than in bean mono-crops (15%). However, for desmodium the opposite was considered to be true, with more blister beetle damage reported by farmers producing desmodium seed (62%) than by those practising “push-pull” technology (29%); significantly more seed-producing than “push-pull” farmers reported blister beetle damage ($\chi^2 = 6.24$, $df = 1$, $P = 0.012$). A small percentage of both groups (9%) reported no difference.

Of the 58 farmers growing desmodium and who mentioned blister beetles as pests, 49 were able to estimate the amount of seed considered to be lost as a result of attack by these beetles. Damage estimates ranged from less than 2.5 kg per hectare to more than 11 kg per hectare which is approximately 2–8% of their seed yield (130 kg/ha). The majority of farmers (47%) estimated the loss at less than 2.5 kg per hectare. Nineteen farmers (32%) estimated yield losses ranging

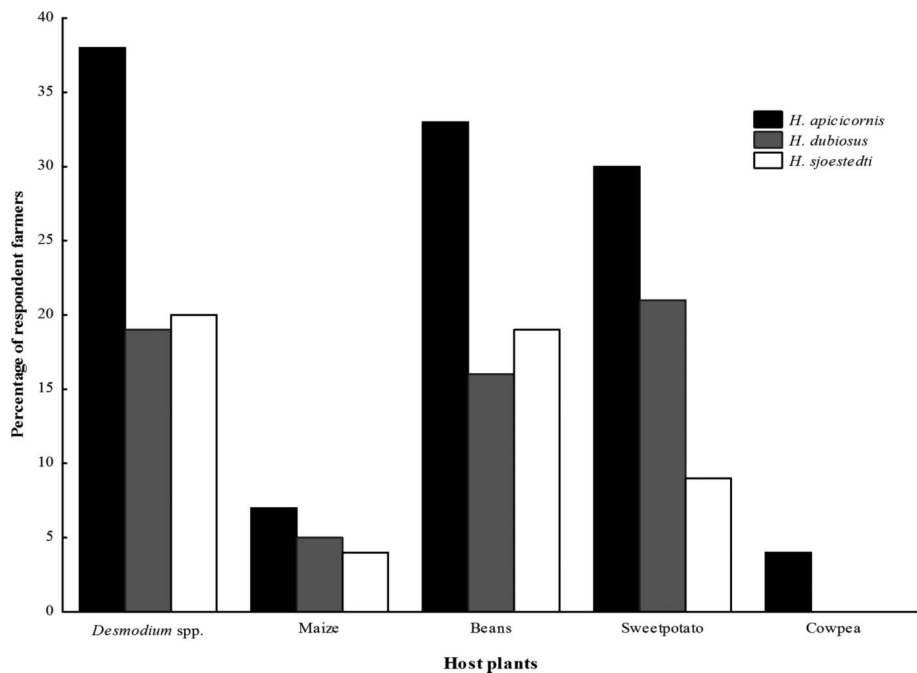


Figure 3. Percentage of respondent farmers who identified three *Hyleus* spp. attacking various crops, with the aid of pictures.

between 2.5 kg and 11 kg per hectare, while only three farmers gave estimated losses of more than 11 kg per hectare.

3.2. Field sampling

3.2.1. Observed pests

Two blister beetle species were recorded during the field sampling: *Hycleus apicicornis* and *H. dubiosus*. The former was the more abundant species (Table 3). Another pest recorded in this study was the African bollworm, *Helicoverpa armigera*. It was found on both desmodium and sweetpotato, although it was present in very low numbers (<10 larvae in each sample site) (Table 3). Other insects collected included the common stink bug, *Nezara viridula* L. (Heteroptera: Pentatomidae) and other coleopteran pests such as *Cylas* spp. (Coleoptera: Curculionidae) on sweetpotato and the black maize beetle, *Heteronychnus arator* Fabricius (Coleoptera: Scarabaeidae) on desmodium. Due to the low abundance of *H. dubiosus*, only *H. apicicornis* was selected for comparison among hosts and sampling locations. The abundance of *H. apicicornis* did not differ between morning and afternoon hours (Marakaru: Wilcoxon Matched Pairs test; $Z = 1.33$, $df = 55$, $P = 0.18$; East Bukusu: Wilcoxon Matched Pairs test; $Z = 0.55$, $df = 37$, $P = 0.58$), except in the Tutii sub-location where significantly more beetles

were recorded in the morning (Wilcoxon Matched Pairs test; $Z = 3.93$, $df = 85$, $P < 0.0001$).

No sampling of desmodium was undertaken in East Bukusu because all plots had been slashed off at the time when farmers were visited. There were no significant differences (Kruskal–Wallis test; $H_{2,24} = 0.775$, $P = 0.679$) in the abundances of beetles on sweetpotato across all sampled sites. A comparison of the abundances of beetles between the two crops was made for the Marakaru and Tutii sub-locations. In Marakaru, significantly more *H. apicicornis* adults were recorded on desmodium than on sweetpotato (Mann–Whitney U-test; $Z_{adj.} = 3.095$, $df = 178$, $P = 0.002$). However, in Tutii, there were significantly more of these beetles on sweetpotato than on desmodium (Mann–Whitney U-test; $Z_{adj.} = -2.080$, $df = 198$, $P = 0.038$).

4. Discussion

Information from the farmers was unlikely to be biased by gender because a balanced sample was taken. Likewise, the majority of farmers had attended school; therefore, opinions regarding knowledge of different pests were not likely to be influenced by different levels of education between different locations. Although farmers were producing all their crops on very small areas of less than one hectare, most farmers were growing six or more crops, most of which were

Table 3. Mean count (\pm SD) of insect pests per quadrant on *Desmodium* spp. and sweetpotato fields in each of the three sub-locations in Bungoma.

| Sub-locations | Host plants/insect pests | Time of occurrence | | Mean total catches |
|---------------|-----------------------------|--------------------|------------------|--------------------|
| | | 09h00–11h00 | 15h00–17h00 | |
| Marakaru | <i>Desmodium</i> spp. | | | |
| | <i>Hycleus apicicornis</i> | 0.51 \pm 0.078 | 0.36 \pm 0.069 | 0.87 \pm 0.109 |
| | <i>Hy. dubiosus</i> | 0.00 \pm 0.000 | 0.01 \pm 0.010 | 0.01 \pm 0.010 |
| | <i>Helicoverpa armigera</i> | 0.01 \pm 0.010 | 0.01 \pm 0.010 | 0.02 \pm 0.014 |
| | <i>Nezara viridula</i> | 0.08 \pm 0.027 | 0.15 \pm 0.048 | 0.23 \pm 0.055 |
| | Sweetpotato | | | |
| | <i>Hycleus apicicornis</i> | 0.22 \pm 0.067 | 0.21 \pm 0.055 | 0.44 \pm 0.096 |
| | <i>Hy. dubiosus</i> | 0.00 \pm 0.000 | 0.00 \pm 0.000 | 0.00 \pm 0.000 |
| | <i>Helicoverpa armigera</i> | 0.01 \pm 0.013 | 0.04 \pm 0.021 | 0.05 \pm 0.025 |
| | <i>Nezara viridula</i> | 0.08 \pm 0.043 | 0.00 \pm 0.000 | 0.08 \pm 0.043 |
| Tutii | <i>Desmodium</i> spp. | | | |
| | <i>Hycleus apicicornis</i> | 0.28 \pm 0.060 | 0.27 \pm 0.053 | 0.55 \pm 0.077 |
| | <i>Hy. dubiosus</i> | 0.00 \pm 0.000 | 0.10 \pm 0.041 | 0.10 \pm 0.041 |
| | <i>Helicoverpa armigera</i> | 0.00 \pm 0.000 | 0.00 \pm 0.000 | 0.00 \pm 0.000 |
| | <i>Nezara viridula</i> | 0.55 \pm 0.007 | 0.38 \pm 0.087 | 0.93 \pm 0.151 |
| | Sweetpotato | | | |
| | <i>Hycleus apicicornis</i> | 0.71 \pm 0.091 | 0.12 \pm 0.046 | 0.83 \pm 0.095 |
| | <i>Hy. dubiosus</i> | 0.12 \pm 0.046 | 0.00 \pm 0.000 | 0.12 \pm 0.046 |
| | <i>Helicoverpa armigera</i> | 0.01 \pm 0.010 | 0.00 \pm 0.000 | 0.01 \pm 0.010 |
| | <i>Nezara viridula</i> | 0.05 \pm 0.022 | 0.20 \pm 0.064 | 0.25 \pm 0.069 |
| East Bukusu | Sweetpotato | | | |
| | <i>Hycleus apicicornis</i> | 0.39 \pm 0.071 | 0.44 \pm 0.070 | 0.83 \pm 0.106 |
| | <i>Hy. dubiosus</i> | 0.02 \pm 0.014 | 0.02 \pm 0.014 | 0.04 \pm 0.020 |
| | <i>Helicoverpa armigera</i> | 0.00 \pm 0.000 | 0.02 \pm 0.014 | 0.02 \pm 0.014 |
| | <i>Nezara viridula</i> | 0.04 \pm 0.020 | 0.01 \pm 0.010 | 0.05 \pm 0.022 |

intercropped. This practice was useful for assessing the occurrence of blister beetles, because farmers' responses to the questionnaire were not based only on their desmodium crop.

Responses to the questionnaire revealed that farmers were generally aware of the blister beetles, even before pictures were shown to them. This was the case for both desmodium and non-desmodium growing farmers and was confirmed by correct identification by the farmers of the plant parts that are damaged by blister beetles on different host plants. Flowers were mentioned as the most severely damaged plant organs, followed by seed. Blister beetle damage of developing seeds has been observed on desmodium in this study (L.N. Lebesa, personal observation). Damage on seeds by blister beetles has also been documented on other crops such as pearl millet (Zethner and Laurence 1988; Lale and Sastawa 2000) and a prairie legume (Evans et al. 1989).

In addition to desmodium, blister beetles were also mentioned by the majority of farmers growing beans and sweetpotato, but by fewer farmers growing maize and cowpea. Cowpea was cultivated by fewer farmers making it less available as a host. However, a multiple choice feeding study in the laboratory confirmed that cowpea was the least preferred crop when compared to desmodium, sweetpotato, okra and beans (L.N. Lebesa, unpublished data). On maize, *H. apicicornis* has been observed to feed on pollen only (L.N. Lebesa personal observation), hence could not have had a serious impact on maize yields and may account for the small number of farmers who noticed its presence on plants. However, in some crops, feeding on pollen by blister beetles may affect the number of grains and thereby reduce yields as was observed with pearl millet in West Africa (Gahukar 1984; Lale and Sastawa 2000). Other than blister beetles, the African bollworm, *Helicoverpa armigera* was also mentioned by a few farmers as occurring on desmodium. This observation was supported by field sampling where the pest was found in very low numbers (<10 larvae at each site), although *H. armigera* can be a problem for desmodium seed production (Boonman 1993).

Although blister beetles were mentioned as pests by most respondents, few farmers were using any control measures. This could be attributed to a number of factors, some of which were highlighted in the interviews. These included lack of knowledge of effective control methods and non-availability and/or high cost of chemical pesticides, which have also been mentioned previously (Wightman and Wightman 1994; Mendesil et al. 2007). The practice of collecting beetles and crushing them, mentioned by a few farmers, may be harmful since farmers handle the beetles with bare hands. Blister beetles produce cantharidin (McCormick and Carrel 1987; Nikbakhtzadeh and Targari 2002), a toxic terpenoid responsible for blistering if it comes into contact with skin (Carrel and Eisner 1974;

McCormick and Carrel 1987). Levels of cantharidin in *Hycleus* spp. have been found to vary from negligible concentrations to high levels (Mebs et al. 2009). Although in this particular study, farmers did not complain about blistering, suggesting that levels may be low, there may be need for caution in this regard in the longer term.

Farmers rated blister beetle damage as more serious on the seed bulking plots (desmodium monocrops) than on the "push-pull" stands (desmodium intercropped with maize). This is most likely due to less efficient location of desmodium (the preferred host) by the pest in a "push-pull" system. It is also possible that the impact on desmodium is lower in the mixed stands because beetles alternate between the two hosts to obtain different food resources to balance nutritional requirements (Bernays and Minkenberg 1997; Marques et al. 2000; Cook et al. 2004; Miura and Ohsaki 2004).

Although the field survey to determine the abundance of blister beetles on different crop hosts was carried out during the short rainy season only, which is characterized by low populations of blister beetles, the outcome largely supported the perceptions of farmers. According to the farmers, the abundance of blister beetles on desmodium is slightly higher than on sweetpotato. However, this was not the case in either site sampled. On the other hand, follow-up collections of *H. apicicornis* on both crops at full flowering stage were almost the same on the two crops (L.N. Lebesa, personal observation). However, the blister beetle *Hycleus dubiosus* and the bollworm *Helicoverpa armigera* were more abundant on sweetpotato than on desmodium. Moreover, although the abundance of blister beetles on desmodium was higher at the Marakuru than the Tutii sub-location, where blister beetles were more abundant on sweetpotato than on desmodium, an overall comparison shows that occurrence of beetles was similar on the two crops. Thus, sweetpotato seems to be a good alternative host for this pest, and it would be interesting to explore the effect of intercropping sweetpotato with desmodium in seed production systems as a tactic in the management of blister beetles.

In conclusion, the results of this survey show that the farmers in the study area are cognizant of the blister beetles, especially *Hycleus apicicornis*, as a pest of desmodium. Their perceptions have been confirmed by field surveys. If not controlled, blister beetles have the potential to reduce the yield of desmodium seed. This in turn may negatively affect the success of the "push-pull" system of crop protection which requires desmodium as a companion plant to suppress *Striga* (Cook et al. 2007).

Acknowledgements

Research funds for this study were provided by Gatsby Charitable Foundation (UK) and the Kilimo Trust (East Africa). DAAD, the German Academic Exchange Service,

provided a grant to cover living expenses in Kenya for the first author. The University of Pretoria and the Lesotho Government are also acknowledged for providing both financial and logistical support in South Africa. We would like to express our gratitude to the following persons: Prof. Marco Bologna, Roma TRE University who identified the blister beetles free of charge; Mr J. Pitchaar and Dr A. Amudavi for commenting on the design of the questionnaires; Dr E.M. Njuguna, and anonymous referees for critical evaluation of the manuscript; Dr C. Midega for his comments on an earlier version of this work; the icipe field staff based in Bungoma and Kitale, specifically Aloice Ndiege and Phillip Akelo, who provided logistical support.

References

- Agnew ADQ, Agnew S. 1994. Upland Kenya wild flowers – a flora of the ferns and herbaceous flowering plants of upland Kenya. 2nd edition. Nairobi: East Africa Natural History Society.
- Abate T, Ampofo JKO. 1996. Insect pests of beans in Africa: their ecology and management. *Annu Rev Entomol.* 41:45–73.
- Bernays EA, Minkenberg OPJM. 1997. Insect herbivores: different reasons for being a generalist. *Ecology.* 78:1157–1169.
- Bologna MA, Pinto JD. 2002. The Old World genera of Meloidae (Coleoptera): a key and synopsis. *J Nat Hist.* 36:2013–2102.
- Boonman JG. 1993. East Africa's grasses and fodders: their ecology and husbandry. Chapter 10: Legumes in sown and grazed pastures. Dordrecht: Kluwer Academic Publishers. p. 190–206.
- Carrel JE, Eisner T. 1974. Cantharidin: potent feeding deterrent to insects. *Science.* 183:755–757.
- Cook BG, Pengelly BC, Brown SD, Donnelly JL, Eagles DA, Franco MA, Hanson J, Mullen BF, Partridge IJ, Peters M, Schultze-Kraft R. 2005. Tropical Forages: an interactive selection tool [CD-ROM]. Brisbane (Australia): CSIRO, DPI&F (Qld), CIAT and ILRI.
- Cook SM, Khan ZR, Pickett JA. 2007. The use of push–pull strategies in integrated pest management. *Annu Rev Entomol.* 52:375–400.
- Cook SM, Murray DA, Williams IH. 2004. Do pollen beetles need pollen? The effect of pollen on oviposition, survival, and development of a flower-feeding herbivore. *Ecol Entomol.* 29:164–173.
- Ebenebe AA, Van den Berg J, Van der Linde TC. 2001. Farm management practices and farmers' perceptions of stalk-borers of maize and sorghum in Lesotho. *Int J Pest Manage.* 47:41–48.
- Evans EW, Smith CC, Gendron RP. 1989. Timing of reproduction in a prairie legume: seasonal impacts of insects consuming flowers and seeds. *Oecologia.* 78:220–230.
- Gahukar RT. 1984. Insect pests of pearl millet in West Africa: a review. *Trop Pest Manage.* 30:142–147.
- Gahukar RT. 1991. Pest status and control of blister beetles in West Africa. *Trop Pest Manage.* 37:415–420.
- Hall MJR. 1984. Trap-oriented behaviour of red-banded blister beetles, *Mylabris designata* var. *hacolyssa* Rochebrune (Coleoptera: Meloidae), in the Sudan. *Bull Entomol Res.* 74:103–112.
- Healey JF. 1990. *Statistics: A tool for social research.* 2nd edition. Belmont (CA): Wadsworth Publishing.
- Hill D.S. 1975. *Agricultural insect pests of the tropics and their control.* 1st edition. London: Cambridge University Press.
- Hillocks RJ, Minja E, Mwaga A, Nahdy MS, Subrahmanyam P. 2000. Diseases and pests of pigeonpea in eastern Africa: a review. *Int J Pest Manage.* 46:7–18.
- Khan ZR, Amudavi DM, Midega CAO, Wanyama JM, Pickett JA. 2008b. Farmers' perceptions of a “push–pull” technology for control of cereal stemborers and *Striga* weed in western Kenya. *Crop Prot.* 27:976–987.
- Khan ZR, Hassanali A, Overholt W, Khamis TM, Hooper AM, Pickett JA, Wadhams LJ, Woodcock CM. 2002. Control of witchweed *Striga hermonthica* by intercropping with *Desmodium* spp., and the mechanism defined as allelopathic. *J Chem Ecol.* 28:1871–1885.
- Khan ZR, Midega CAO, Amudavi DM, Hassanali A, Pickett JA. 2008a. On-farm evaluation of the “push–pull” technology for the control of stemborers and striga weed on maize in Western Kenya. *Field Crops Res.* 106:224–233.
- Khan ZR, Midega CAO, Hassanali A, Pickett JA, Wadhams LJ, Wanjoya A. 2006b. Management of witchweed, *Striga hermonthica*, and stemborers in sorghum, *Sorghum bicolor*, through intercropping with greenleaf desmodium, *Desmodium intortum*. *Int J Pest Manage.* 52:297–302.
- Khan ZR, Pickett JA, Van den Berg J, Wadhams LJ, Woodcock CM. 2000. Exploiting chemical ecology and species diversity: stem borer and striga control for maize and sorghum in Africa. *Pest Manage Sci.* 56:957–962.
- Khan ZR, Pickett JA, Wadhams LJ, Hassanali A, Midega CAO. 2006a. Combined control of *Striga hermonthica* and stemborers by maize–*Desmodium* spp. intercrops. *Crop Prot.* 25:989–995.
- Lale NES, Sastawa BM. 2000. Evaluation of host plant resistance, sowing date modification and intercropping as methods for the control of *Mylabris* and *Coryna* species (Coleoptera: Meloidae) infesting pearl millet in the Nigerian Sudan savanna. *J Arid Environ.* 46:263–280.
- Lebesa LN, Khan ZR, Hassanali A, Pickett JA, Bruce TJA, Skellern M, Krüger K. 2011. Responses of the blister beetle *Hycleus apicicornis* to visual stimuli. *Physiol Entomol.* 36:220–229.
- Marques ESA, Price PW, Cobb NS. 2000. Resource abundance and insect herbivore diversity on woody Fabaceous desert plants. *Environ Entomol.* 29:696–703.
- McCormick JP, Carrel JE. 1987. Cantharidin biosynthesis and function in meloid beetles. In: Prestwitch GD, Blomquist GJ, editors. *Pheromone biochemistry.* Orlando: Academic Press. p. 307–350.
- Mebs D, Pogoda W, Schneider M, Kauert G. 2009. Cantharidin and demethylcantharidin (palasonin) content of blister beetles (Coleoptera: Meloidae) from southern Africa. *Toxicon.* 53:466–468.
- Mendesil E, Abdeta C, Tesfaye A, Shumeta Z, Jifar H. 2007. Farmers' perceptions and management practices of insect pests on stored sorghum in southwestern Ethiopia. *Crop Prot.* 26:1817–1825.
- Miura K, Ohsaki N. 2004. Diet mixing and its effect on polyphagous grasshopper nymphs. *Ecol Res.* 19:269–274.
- Nikbakhtzadeh MR. 2004. Transfer and distribution of cantharidin within selected members of blister beetles (Coleoptera: Meloidae) and its probable importance in sexual behaviour. PhD dissertation. Universität Bayreuth, Germany.
- Nikbakhtzadeh MR, Tirgari S. 2002. Cantharidin component of Iranian blister beetles (Col: Meloidae) and their differences between Iranian and exotic species. *Iranian J Publ Health.* 31:113–117.
- Obopile M, Munthali DC, Matilo B. 2008. Farmers' knowledge, perceptions and management of vegetable pests and diseases in Botswana. *Crop Prot.* 27:1220–1224.

- Özbek H, Szaloki D. 1998. A contribution to the knowledge of the Meloidae (Coleoptera) fauna of Turkey along with new records. *Tr J Zool.* 22:23–40.
- [PANESA/ARNAB] Pastures Network for Eastern and Southern Africa/African Research Network for Agricultural By-products. 1990. Utilization of research results on forage and agricultural by-product materials as animal feed resources in Africa. Proceedings of the first joint workshop held in Lilongwe, Malawi; 1988 Dec 5–9; Addis Ababa (Ethiopia): PANESA/ARNAB.
- Paterson RT, Karanja GM, Roothaert RL, Nyaata OZ, Kariuki IW. 1998. A review of tree fodder production and utilization within smallholder agroforestry systems in Kenya. *Agrofor Syst.* 41:181–199.
- Pickett JA. 1998. Extended summaries, SCI Pesticides Group Meeting: Semiochemicals in Integrated Crop Management: Commercial prospects. *Pestic Sci.* 54:290–299.
- Pickett JA, Hamilton ML, Hooper AM, Khan ZR, Midega CAO. 2010. Companion cropping to manage parasitic plants. *Ann Rev Phytopathol.* 48:161–177.
- Scholtz CH, Holm E. 1986. *Insects of Southern Africa.* Mayville, Durban: Butterworth Publishers (Pty) Ltd.
- Selander RB. 1986. Rearing blister beetles (Coleoptera, Meloidae). *Insecta Mundi.* 1:209–220.
- Tanzubil PB, Yakubu EA. 1997. Insect pests of millet in Northern Ghana. 1. Farmers' perceptions and damage potential. *Int J Pest Manage.* 43:133–136.
- Tefera T. 2004. Farmers' perceptions of sorghum stem-borer and farm management practices in eastern Ethiopia. *Int J Pest Manage.* 50:35–40.
- Wightman JA, Wightman AS. 1994. An insect, agronomic and sociological survey of groundnut fields in southern Africa. *Agric Ecosyst Environ.* 51:311–331.
- Zethner O, Laurence AA. 1988. The economic importance and control of the adult blister beetle *Psalydolytta fusca* Olivier (Coleoptera: Meloidae). *Trop Pest Manage.* 34:407–412.
- Zhu F, Lei C-L, Xue F. 2005. The morphology and temperature-dependent development of *Mylabris phalerata* Pallas (Coleoptera: Meloidae). *Coleopt Bull.* 59:521–527.