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Feasibility of the Trap Cropping System for the Management of Hemipteran Bugs on Mungbean, Vigna radiata (L.) Wilczek in Nepal【Research report】

應用陷阱作物管理尼泊爾綠豆Vignaradiata (L.) Wilczek半翅目害蟲之可行性【研究報告】

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Abstract

This study was conducted on hemipteran bugs on mungbean in Nepal. A trap crop of a variety preferred by the bugs was planted along with the main crop. The tests were performed using a selection of six of the most preferred mungbean varieties [VC6173A, VC6153B-20G, VC3960A-88, Kalyan, Pratikchha, and Saptari local (as the control)] relative to the Saptari local variety. Significant differences were recorded in the number of bugs among the six varieties, with a maximum number of bugs in VC6173A (3.25 bugs/plant) showing the lowest yield. Three different trap crop designs were employed in the field. There was a significant difference between variety Pratikchha as the main crop and variety VC6173A used as the trap crop in two of the designs. The data suggested that VC6173A is a probable trap crop and that those two designs can be employed in the field in Nepal.

摘要

本研究利用不同害蟲偏好之陷阱作物與主要作物同時耕作，針對尼泊爾半翅目害蟲進行蟲害管理。選用六種綠豆品種[VC6173A, VC6153B-20G, VC3960A-88, Kalyan, Pratikchha, and Saptari local (as the control)] 與Saptari原生種比較。結果顯示所記錄到半翅目害蟲之數量在不同品種間具有顯著性差異，以VC6173A (3.25 bugs/plant) 害蟲數量最多且其產量最少。以三種不同陷阱作物在田間進行耕作規劃，發現以Pratikchha作為主要作物而以VC6173A作為陷阱作物之方式，與其他兩種方式具有顯著性差異。結果顯示VC6173A為最適合在尼泊爾綠豆種植之陷阱作物。

Key words: Heteropteran bugs, trap crops, field designs, varieties, yield

關鍵詞: 半翅目害蟲、陷阱作物、田間設計、種類、產量。

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Feasibility of the Trap Cropping System for the Management of Hemipteran Bugs on Mungbean, *Vigna radiata* (L.) Wilczek in Nepal

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ABSTRACT

This study was conducted on hemipteran bugs on mungbean in Nepal. A trap crop of a variety preferred by the bugs was planted along with the main crop. The tests were performed using a selection of six of the most preferred mungbean varieties [*VC6173A*, *VC6153B-20G*, *VC3960A-88*, *Kalyan*, *Pratikchha*, and *Saptari local* (as the control)] relative to the *Saptari local* variety. Significant differences were recorded in the number of bugs among the six varieties, with a maximum number of bugs in *VC6173A* (3.25 bugs/plant) showing the lowest yield. Three different trap crop designs were employed in the field. There was a significant difference between variety *Pratikchha* as the main crop and variety *VC6173A* used as the trap crop in two of the designs. The data suggested that *VC6173A* is a probable trap crop and that those two designs can be employed in the field in Nepal.

Key words: Heteropteran bugs, trap crops, field designs, varieties, yield

Introduction

The mungbean is an important crop in Nepal (AVRDC, 1998). Although the government is attempting to increase mungbean production, their efforts are being hampered by a variety of factors. One of these obstacles is the gradual increase of hemipteran pests (Neupane *et al*., 2003). Among the 198 globally reported mungbean insect pests, 64 species attack the mungbean crop in India (Lal, 1985). However, in Nepal the insect pest incidence among regions and among varieties vary greatly. The main heteropteran pests in Nepal infesting mungbean include *Riptortus linearis, Nazara viridula*, *Dolycoris baccarum*, *Piezodorus hybueri*, and *Melanacanthus scutellaris* (Neupane *et al.,* 2003). The Heteropteran bugs are becoming a bigger

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factor in the qualitative and quantitative loss in soybean and mungbean (Kim *et al.*, 1992; Mizutani *et al.*, 1999; Neupane *et al.*, 2003) and tree fruits (Chung *et al.*, 1995) in Korea, Japan as well as Nepal. Adults and nymphs alike feed on both vegetative and reproductive mungbean plant tissues, and they attain high population densities during the flowering and poding stages.

Vigna radiata is an indigenous vegetable legume. It is one of the most important pulse crops in South and Southeast Asia (Chadha, 2010). Improved varieties were introduced in Nepal by the National Grain Legume Research Program (NGLRP) from the Asian Vegetable Research and Development Research Center (AVRDC) and are being widely cultivated after their release. These improved varieties are well adapted to the spring, summer and autumn seasons of the low hills and the Terai agro-ecosystems of Nepal, and in the Indo-Gangetic Plains (Khanal *et al*., 2004, 2005). It fits in with the diverse cropping systems that exist from the Terai to the foothills of Nepal. It has a deep tap root system that allows the crop to effectively utilize the nutrients and moisture from various strata of the soil. Moreover, it breaks the insect-pest and disease cycle, thereby enhancing the sustainability of the health of the soil and the overall farming system (Khanal *et al*., 2005). Since the introduction of chemical pesticides, Nepalese farmers rely almost exclusively on chemical control to combat the problem of insect pests. Since using pesticide is costly and causes public concern, management tactics that are more economically and environmentally sound such as trap cropping are needed (Yoon and Jung, 2008; Lu *et al.*, 2007). In addition, pesticide avoidance by the bugs has been reported (Choi *et al.*, 2005). Trap cropping is a promising, environmentally sound approach to managing insect pests in agricultural and forest systems. It should be viewed in the larger context of landscape ecology (Klopatek and Gardner, 1999). Prior to the introduction of modern synthetic insecticides, trap cropping was a common method of pest control. The recent resurgence of interest in trap cropping as an IPM tool is the result of concerns about the potential negative effects of pesticides on human health and the environment, pesticide resistance, and economic considerations. Trap cropping has been suggested as a tactic for the management of stinkbugs (McPherson and Newsom, 1984; Rea *et al*., 2002a). Hemipteran bugs and a leguminous crop make a good setting for testing trap cropping. Lu *et al*. (2009) reported the potential of *Vigna radiata* as a trap crop for managing *Apolygus lucorum* on Bt. cotton.

The practice of trap cropping is based on the exploitation of the preferences by insects for certain host plants, based on visual, tactile or olfactory cues (Hokkanen, 1991; Foster and Harris, 1997; Schoonhoven *et al.*, 2005; Shelton and Badenes-Perez, 2006; Cook *et al.*, 2007). By interplanting a highly attractive plant species together with the susceptible crop, the pest insect can be attracted and diverted from the target crop. Hokkanen (1991) reported that the planting time of the trap crops is crucial for the management of bugs. Combining the biological control of trap cropping with chemical control may enhance the hemipteran pest management. Rational use of insecticides within the trap crop can lower the overall use of pesticides and the resulting associated environmental impact (Hokkanen, 1991; Shelton and Badenes-Perez, 2006; Yoon and Jung, 2008). Modalities based on the deployment of the trap crop have been reviewed by many scientists (Pyke *et al.*, 1987; Millar and Cowles, 1990; Foster and Harris, 1997; Hoy *et al*., 2000; Khan *et al.*, 2001; Boucher *et al.*, 2003; Shelton and Badenes-Perez, 2006). Boucher *et al*. (2003) reported perimeter trap cropping designs for pest management. The use of field margin manipulation for insect control is becoming common in IPM (Shelton and

Badenes-Perez, 2006). Yoon and Jung (2008) reported the effectiveness of arranging the trap crop around the perimeter of soybeans to protect them from *Riptortus clavatus*. Trap cropping has been successfully used to control the stinkbug complex, as well as other bugs in New Zealand, Nigeria, Brazil (Correa-Ferreira and Moscardi, 1996; Rea *et al*., 2002b). However, this type of trap cropping is rarely performed in Nepal. Thus, the present study was conducted to select the most preferred mungbean variety i.e., *VC6173A* as the trap crop candidate and to examine its potential as a trap crop for heteropteran bugs in the mungbean production in Nepal. One-year plant suitability trials were conducted to compare the bug's attraction to each variety of mungbean. The effect of the trap crop design on the heteropteran bug infestation was determined by field experiments.

Material and Methods

Comparative variety attraction trials

A variety of attraction trials were carried out at the National Grain Legume Research Program (NGLRP), in Nepal. We established plots measuring 4 × 2 m. Using a complete randomized design (CRD) we created 40 × 10 cm spaces within these plots, in which we then planted six different mungbean varieties (*VC6173A*, *VC6153B-20G, VC3960A-88*, *Kalyan*, *Pratikchha*, *Saptari local* in 2008. *Saptari local* was used as the control. Except for *Saptari local*, the varieties were introduced from AVRDC lines. The above varieties were chosen based on the fact that they are widely cultivated and have a high yield potential. Plots were subsequently managed using identical agronomic practices, without the use of insecticides. Each experiment was replicated five times.

Sampling consisted of a visual inspection of the entire plant for the presence of bug adults, and total number of bugs was recorded. During each sampling event, 20 plants were randomly selected and the total number of bugs for each plant per treatment plot was recorded every 7 days. We surveyed the numbers of bugs from 14 March to 21 May 2008 in each plot. This sampling period coincided with the time that the bugs were present in the mungbean fields in Nepal.

Trap crop designs

A 50m^2 mungbean field (measuring 10 m long × 5 m wide) was set up for each of the three designs at the National Grain Legume Research Program, Nepal. The trap crop was selected based on the result from the previous attraction experiment that demonstrated a high preference by the bugs for *VC6173A*. Thus, *VC6173A* was used as the trap crop, and *Pratikchha* was designated the main crop for comparing the trap crop designs. The trap crop was planted 10 days earlier than the main crop. The spacing between the main crop and the trap crop was 1m in all the designs (Fig. 1).

Design 1: The main crop plot measured 5 × 10 m. The main crop (*Pratikchha*) was flanked on both long (10 m) sides by the trap crop (*VC6173A*). The space between the trap crop and the main crop was 1 m. The trap crop consisted of a double row on each long side.

Design 2: The main crop plot measured 5 × 10 m. The main crop (*Pratikchha*) was surrounded by the trap crop (*VC6173A*). The space between the trap crop and the main crop was 1 m.

Design 3: The main crop plot measured 5 × 10 m, and was divided into 4 equal subplots measuring 4 × 1.5 m. The space between the trap crop and the main crop (*Pratikchha*) was 1 m.

The trap crop row (*VC6173A*) formed a cross 10 m high × 5 m wide dividing the main crop plot into four equal parts.

Standard agronomic practices were applied, with the exception of the spraying of insecticides spraying. No insecticides

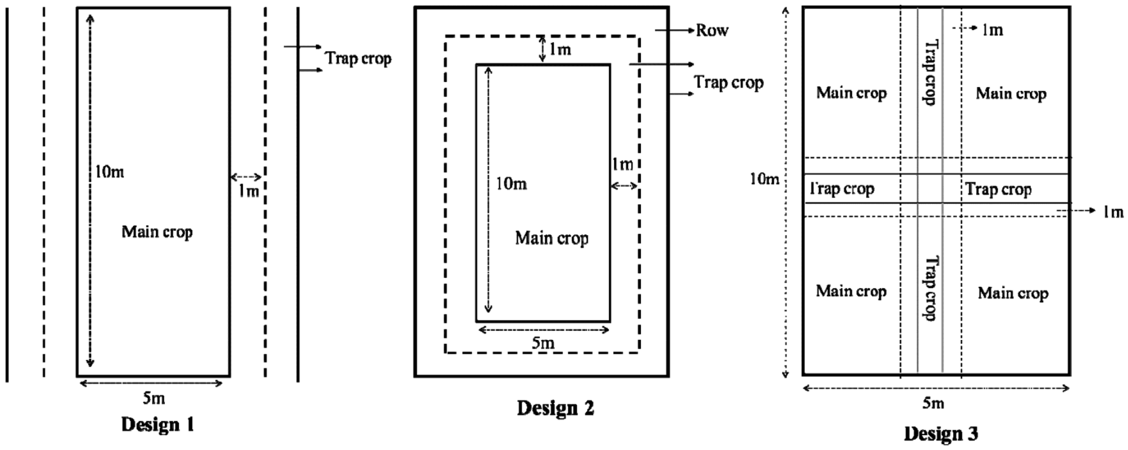

Fig. 1. Schematic of the three experimental trap designs, with the trap crops an equal distance (1 m) removed from the main crops.

were applied to the field during the season.

The above experiments were each replicated five times.

To evaluate the effect of the trap crop arrangements on the bug infestation, 20 randomly selected plants of the main crop and 20 randomly selected plants of the trap crop were monitored from14 March to 21 May 2009. The total number of bugs on the selected plants in each treatment plot was recorded every 7^{th} day.

Statistical analysis

The preference ratio was calculated by using the number of hemipterans on the main crop over the number of insects of each individual crop variety including the trap crop. The bug population density in the trap crop and the main crop fields were analyzed by means of the *t*-test ($p < 0.05$). The yield parameter for each variety was analyzed by using the ANOVA procedure. The relationship between the yield and the mean bug density was analyzed by linear regression (SAS, 2009).

Results

Comparative variety attraction trials

The assessment of pest pressure on the treatment by different varieties indicated that the hemipteran bug population differed significantly ($F = 2.92$, $df = 23$, $p = 0.04$) (Fig. 2). The mean number of hemipteran bugs was highest in the *VC6173A* variety, and lowest in *Partikchha* followed by *Saptari local*. Since *Partikchha* is the main variety grown in the Nepalese plains, we used the pest pressure on *Partikchha* to compared the preferences. The preference for *VC6173A* was 280% relative to the main variety, followed by 220% for *VC6153B-20G* and 140% for *VC3960A-88* (Table 1). For all treatments the most dominant (~35%) hemipteran bugs were *R. linearis*, followed by *N. viridula*, *D. baccarum*), *M. scutellaris*) and *P. hybueri*. There was a significant difference in grain yield among the varieties ($F = 3.14$, $df = 23$, $p = 0.05$). In the field trial the highest yield was recorded for *Partikchha* (304.85 g/50 m^2) and the lowest yield for VC6173A (153.53 g/50 m^2) (Fig. 3).

There was a significant linear relationship between pest density and crop yield ($F = 3.75$, $df = 23$, $p = 0.02$). A negative association was found between bug density and yield;

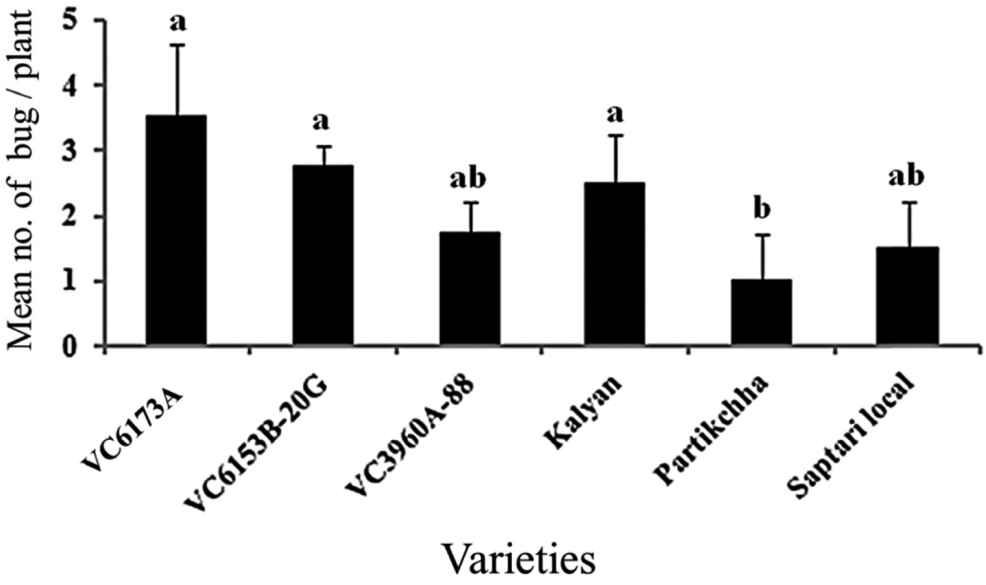

Fig. 2. Mean number of bugs on 6 mungbean varieties (*VC6173A*, *VC6153 B-20G*, *VC3960 A-88*, *Kalyan*, *Pratikchha*, *Saptari local*).

Table 1. Mean number of bugs per sample and the preference ratio with respect to the main crop (*Partikchha*) (Preference ratio = 1)

Variety	No. of bugs (mean ± SE)	Preference	*t-value*	*DF*	*p-value*
VC6173A	3.25 ± 0.34	0.38	7.81	3	0.004
VC6153B-20G	2.75 ± 0.28	0.45	9.4	3	0.002
VC3960A-88	1.75 ± 0.25	0.71	2.21	3	0.113
Kalyan	2.53 ± 0.25	0.5	6.49	3	0.007
Partikchha	1.25 ± 0.18	1	-	3	
Saptari local	1.51 ± 0.25	0.83	1.17	3	0.325

Y = -59.65X + 342.78, where "Y" is the number of bugs and "X" is the yield (Fig. 4).

Trap crop designs

In design 1 (*D1*) where the main crop was flanked on two sides by the trap crop (t = -3.95, df = 6, p = 0.007) (Fig. 5) the bugs densities on the main crop were significantly lower than on the trap crop. A similar significant difference was found in design 2 (*D2*) in which the main crop was surrounded by the trap crop (t = -4.06, df = 6, p = 0.006). However, in design 3 (*D3*), there was no difference of the hemipteran bug densities between the main crop and the trap crop (t = -2.16, df = 6, p = 0.08) (Fig. 5). This data shows the effectiveness of a trap crop for managing the bug population on mungbean under field conditions. Thus, *VC6173A* could be a proper candidate for combating the bug problem on the mungbean crop.

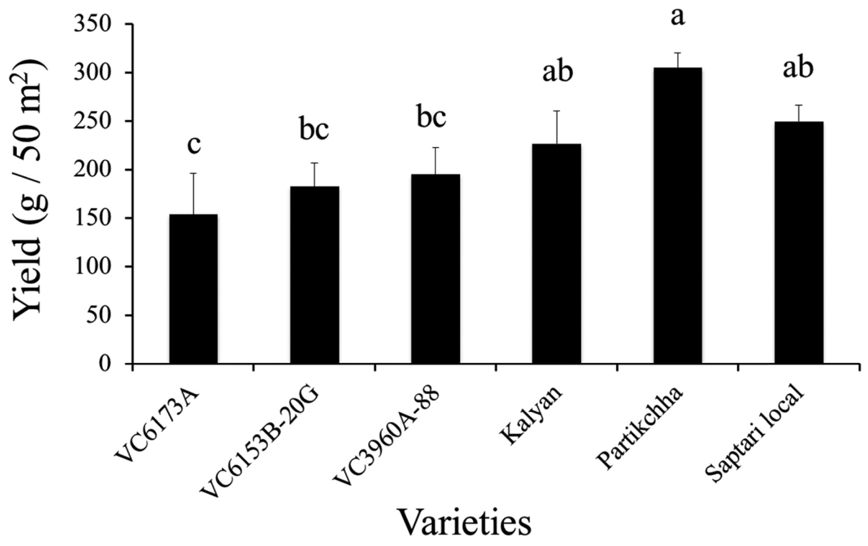

Fig. 3. Yield (mean ± SE) on 6 mungbean varieties (*VC6173A*, *VC6153 B-20G*, *VC3960 A-88*, *Kalyan*, *Pratikchha*, *Saptari local*)

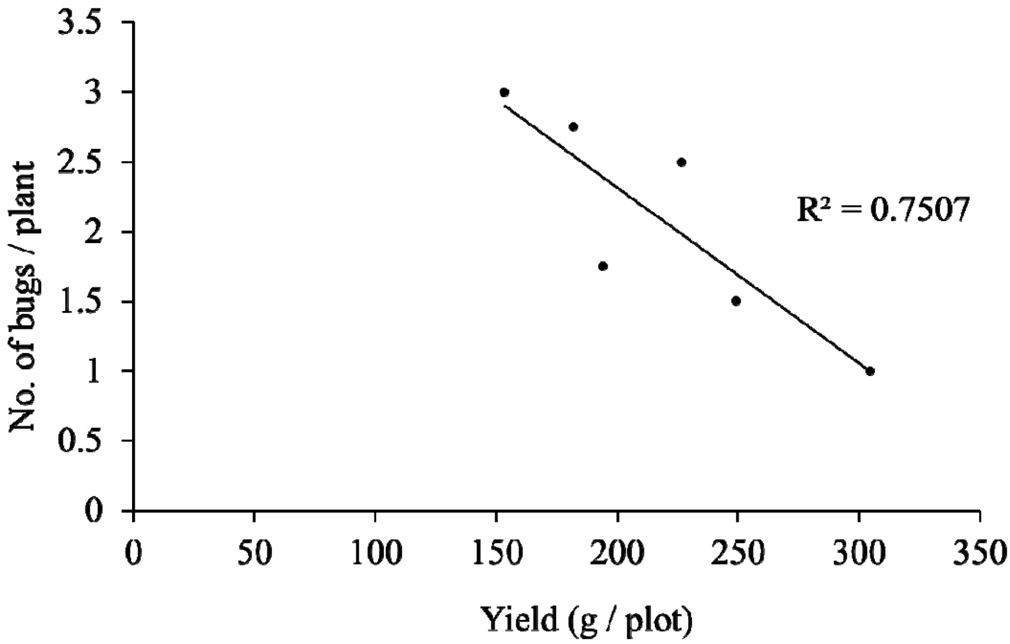

Fig. 4. The relationship between mungbean yield and number of bugs in the mungbean fields of Nepal, 2008.

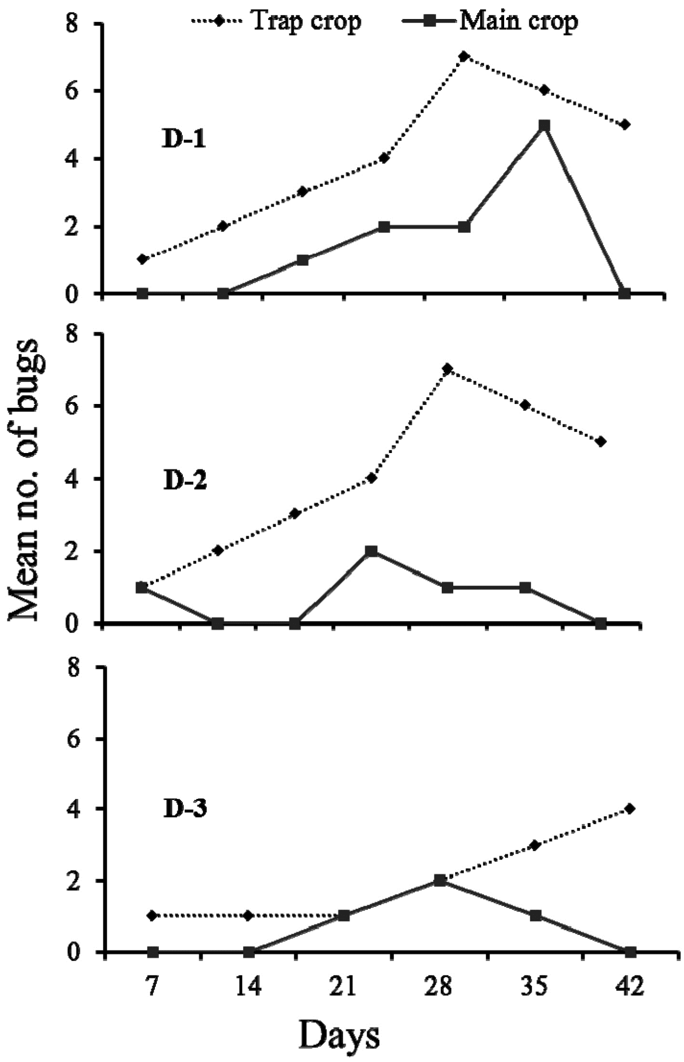

Fig. 5. Population density of the bugs in the trap crop and main crop in the 3 different designs at the day of observation (D1 = design 1, D2 = design 2 and D3 = design 3).

Discussion

This study showed the possibility of the implementation of trap cropping for the management of hemipteran bugs on mungbean crops. The pest pressure on mungbean depends on the variety. The most preferred variety (*VC6173A*) could serve for attracting hemipteran pests and diverting their movement to the main crop. Many phytophagous insects exhibit a clear preference for certain plant species (Schoonhoven *et al.*, 2005). The study of such host plant preference is the basis for the development of pest management strategies, such as ethological control (e.g., the use of chemical attractants for monitoring or mass trapping) and trap crops (Foster and Harris, 1997; Schoonhoven*et al.*, 2005). The diversification of crops can influence host-plant finding by the pest, and result in an interruption of the development of the pest population. A specific soybean crop was used as a trap crop to protect the main soybean crop from stinkbugs in the USA (Hokkanen, 1991). Lu *et al.* (2009) confirmed that bugs prefers mungbean over cotton and that this host-plant preference may be mediated by volatile cues from both laboratory and field experiments.

Although a trap crop can effectively attract adult bugs, some bugs will remain on the main crop, thus requiring additional intervention such as insecticide spray or bio-control. Mungbean strips effectively attract adult *Apolygus lucorum*, *A. lucorum* densities on cotton, but still exceeded the economic threshold if no insecticide application was made on the cotton crop (Lu *et al.*, 2009). Similar findings were made with cantaloupe as a trap crop for *Bemisia tabaci* in cotton (Castle, 2006). Insecticide was applied to control *Bemisia tabaci* on the cantaloupe trap crop, thereby preventing adult dispersal to the main cotton crop. Heteropteran bugs have great flight capability, and trap crop plots can therefore also easily serve as source habitats from which these bugs may re-infest the main crop. Hence, an effective hemipteran management that uses trap cropping should include the prevention of such re-infestations. Aside from recurrent insecticide applications within the trap crop, a variety of other measures can be used to manage the targeted pest insect. Semiochemical and pheromone baits can also be deployed within trap crops (Hokkanen, 1991; Vernon *et al.*, 2000). Repellent non-host crops, synthetic repellents, antifeedants and alarm pheromones can also increase the effectiveness of a trap crop, but they all require further study (Cook *et al.*, 2007). Also, the use of various plant species planted in a similar way as a trap crop can greatly enhance control of a key pest (Seal *et al.*, 1992; Muthiah, 2003).

Trap crops that provide suitable resources or (shelter) for the natural enemies of the pest insect may further contribute to suppressing the pest populations in the trap crop strips or the broader cropping field (Mensah and Sequeira, 2004; Yoon and Jung, 2009). Yoon and Jung (2009) showed that there was a high potential for enhancing biological control by the trap crop attracting not only the pests, but also by serving as a reservoir for the natural enemies of the pests. Tillman and Mullinix (2004) reported that a sorghum trap crop used to manage *Helicoverpa armigera* also increased therate of parasitism by *Trichogramma chilonis*. Mensah (1999) found that the population density of predators recorded in alfalfa strips was higher than in the cotton crop. In our study, we found a high abundance of several predators, including ladybird beetles, lacewings, and spiders in the mungbean strips. However, the effectiveness of these predators has not been assessed (personal observation). Shelton and Badenes-Perez, (2006) described that by diverting insect pests away from the main crop, trap crops can also reduce insect pest populations by enhancing the populations of the pests' natural enemies within the field. The important insect characteristics that determine whether an insect is suitable for management by trap crops are; the stage of the insect targeted by the trap crop and the insect's ability to direct its movement, its migratory behavior (mobility and mode of colonization), and its host-finding behavior (pre-alighting versus post-alighting). The stage of the insect is of critical importance in designing an effective trap crop strategy.

The size of an effective trap crop may vary greatly, depending in part on the mobility of the target pests. Maharjan and Jung (2009) provided distance estimates for some of the hemipteran bugs such as *Riptortus clavatus*, and estimated that they could fly 1.6 to 5.1 km at an average speed of 0.8 m/s. Thus, the distance could be very important when considering community-wide trap crop arrangement (Sevacherian and Stern, 1974; Mensah andKhan, 1997; Michaud *et al.*, 2007). However, even on a smaller scale such as a single field, the size of the trap crop is directly related to the crop yield. Hokkanen (1991) estimated that the general size should be about 10% of the crop area.

In the three proposed designs, trap crops were planted 10 days prior to the planting of the main crop. Shelton and Badenes-Perez (2006) reported that trap crops can be planted earlier and/or later than the main crop to enhance the attractiveness of the trap crop to the targeted insect pest. However, many studies on trap crops found that for an effective control of heteropteran bugs the trap crop must be of an adequate area and be located the optimum distance away from the main crop..

From our experiment we can cautiously conclude that simply manipulating the landscape and selecting the appropriate trap crop may be a good option to manage mungbean bugs. However, a better understanding of the chemical pressures, pest biology and ecological interactions under diverse environmental conditions are required.

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應用陷阱作物管理尼泊爾綠豆 *Vignaradiata* (L.) Wilczek 半翅目害蟲之可行性

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摘　　要

本研究利用不同害蟲偏好之陷阱作物與主要作物同時耕作，針對尼泊爾半翅目害蟲進行蟲害管理。選用六種綠豆品種 [*VC6173A*, *VC6153B-20G*, *VC3960A-88*, *Kalyan*, *Pratikchha*, and *Saptari local* (as the control)] 與 *Saptari* 原生種比較。結果顯示所記錄到半翅目害蟲之數量在不同品種間具有顯著性差異，以 *VC6173A* (3.25 bugs/plant) 害蟲數量最多且其產量最少。以三種不同陷阱作物在田間進行耕作規劃，發現以 *Pratikchha* 作為主要作物而以 *VC6173A* 作為陷阱作物之方式，與其他兩種方式具有顯著性差異。結果顯示 *VC6173A* 為最適合在尼泊爾綠豆種植之陷阱作物。

關鍵詞：半翅目害蟲、陷阱作物、田間設計、種類、產量。

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