Incidence of Arthropod Pests and Natural Enemies in Rice-Tagbak (*Alpinia Elegans* (Presl.) Schum.) and Vegetable Cropping Systems Without Insecticide Application

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Indigenous cultural practices in pest management provide a valuable resource for sustainable agriculture. Farmer observations provide the clues for management of the agricultural ecosystem which is balanced and sustainable. Rice farmers of Infanta, Quezon use tagbak (*Alpinia elegans* (Presl.) Schum.) stalks for insect pest management thus this practice was validated in field trials conducted at the Central Experiment Station, University of the Philippines Los Baños during the wet season 2005 and the dry season 2006. The use of one-meter tagbak stalks in rice paddies during the dry season reduced green leafhopper and brown planthopper populations by 27% and 40%, respectively. Green leafhopper, the most predominant insect pest and total whitehead count were significantly the least in the tagbak treatment over 4 weeks. However, tagbak stalks were not quite effective in repelling whorl maggots in the dry season. More importantly, tagbak stalks did not reduce the natural enemy populations. During the wet season, tagbak treatment had the highest count of beneficial arthropods. Yield during the dry season was 19% (tagbak) and 36% (chemical) higher than control. These results validate the farmer practice of using tagbak stalks in rice production and can be a complementary pest strategy for IPM in low input or organic rice production. Population densities of arthropods were monitored on cauliflower intercropped with dill and celery, without any insecticide use in experimental fields in 2003. The insect pests included: flea beetles, leafhoppers and mealy bugs as well as beneficial arthropods: ants, dragon flies, spiders and coccinellid beetles. Diamond back moth counts, a major insect pest of crucifers, were very low, However, this cropping system was not adequate to address the cutworm population. For squash, there was greater diversity of beneficial insects under organic culture where there was an apparent early control of leafhopper populations by spiders, which however did not affect the whiteflies population. The level of aphid infestation was low and its decline coincided with the initial appearance of ants. There is a need to validate the results in the mixed herb-vegetable and organic squash cropping systems in field trials.

KEYWORDS: Organic agriculture, habitat management, field borders, natural enemies, intercropping, polyculture

INTRODUCTION

Indigenous cultural practices in pest management provide a valuable resource for sustainable agriculture. Farmer observations provide the clues for management of the agricultural ecosystem which is balanced and sustainable. The wealth of indigenous knowledge includes not only botanical insecticides but also the role of plants, such as weeds or companion plants, which are part of the design of their farms. Insect behavior is affected to a certain extent by chemical cues it perceives in the environment. Volatile compounds are continuously emitted by plants into the air and these may be utilized by herbivores to locate their food plants.

The influence of three-lobed morning glory, *Ipomoea triloba* L. on the population density of the Asian corn borer is an example of common farmer knowledge in some corn producing areas in the Philippines, notably in Negros Oriental and Negros Occidental. Corn borer damage is reduced whenever *I. triloba* is present in corn fields, thus farmers allow this weed to grow at densities which they estimate will not affect yield (Medina et al, 1996; Napao, personal comm.) This was validated by several researchers who determined that there was a statistical significance between weed density and corn borer damage (Magalit, 1983) and low egg mass counts were observed in corn where *I. triloba* was grown as a border (Magsino, 1995). This was due to the emission of a repellent volatile organic chemical, 1-methylethyl propyl disulfide, from both corn and *I. triloba*, which increased when corn was entwined by the weed or metal wire. Field and laboratory trials also showed a reduction in corn borer oviposition, 81–91% whenever *I. triloba* entwined corn (Calumpang et al, 2000).

Rice farmers in Infanta, Quezon use tagbak (*Kolowratia elegans* Presl. or *Alpinia elegans*) for insect pest management. Stalks are positioned vertically in the rice fields as it is believed to repel whorl maggot, stemborer and other flying insects (Magsino, 2005). *A. elegans* Presl, known locally in Tagalog as "tagbak," is a perennial herb found in many tropical countries. Tagbak is a Philippine medicinal plant (BPI, 2010; Oliveros and Bruce, 1991). Two endemic genera, Adelmeria and Kolowratia are now lumped among the biggest genus *Alpinia* (Funakoshi & Fujiyama, 2004).

An organic vegetable garden consisting of several vegetables, herbs and marigold was established at the Vegetable Division of the Institute of Plant Breeding, UPLB. This included crucifers such as cabbage (*Brassica oleracea* Linn.), Chinese cabbage (*Brassica rapa*), cauliflower (*Brassica oleracea*) and broccoli (*Brassica oleracea var. botrytis*) as well as solanaceous vegetables such as eggplant (*Solanum melongena var. esculentum*) and sweet pepper (*Capsicum annuum*.), cucurbits such as ampalaya or bitter gourd (*Momordica charantia* L.), cucumber (*Cucumis sativus* L.), patola or ribbed gourd (*Luffa acutangula* Linn.) and upo or white gourd (*Lagenaria siceraria* (Mol.) Standley), as well as legumes: cowpea (*Vigna unguiculata*), pole and bush sitao (*Vigna unguiculata* (L.) Walp.cv.group Sesquipedalis). Herbs such as mint (*Mentha spicata* L.), several varieties of basil (*Ocimum basilicum*) and lemon grass (*Cymbopogon citratus* (DC.) Stapf) were grown as strips or borders. It was observed that the damage due to the diamond back moth, cabbageworm, fruitflies and eggplant fruit/shoot borer was reduced significantly. This cropping system did not use commercial pesticides, relying purely on some botanical water extracts (Maghirang, R. personal communication). It was noted that there was a need to document the population dynamics in this organic vegetable garden.

Farmers can also exert some degree of control over insect colonization by managing the immediate field surroundings, using border strips that attract beneficials or repel pests which slow, delay or prevent colonization (Gleissman, 2000). Intercropping fits into environmentally acceptable and sustainable vegetable-producing practices. Both economic and ecological conditions must be fulfilled before intercropping-based commercial production methods can be developed (Theunissen, 1994). In Mindanao, radish is planted for pest management in crucifers, that is to attract the parasitoid *Diadegma* to manage the diamond back moth (Remotigue. 2004). It has been demonstrated that interplanting of non-host plants drastically reduced colonization efficiency and substantial population density of the specialized herbivore *Phyllotreta cruciferae*. Diversified systems have taxonomic diversity with relatively complex associated patterns of microclimate which are governed to a certain extent by chemical cues. Thus, insects may experience further difficulty in locating spots of favourable microclimatic conditions that result in associational resistance (Tahvanainen & Root, 1973).

This study sought to verify farmer practice on the use of tagbak stalks in rice insect pest management as well as determine the plant-insect interaction in vegetable cropping systems without insecticide use, by documenting the insect infestation cycle in an established organic vegetable garden so that scientists can further integrate the findings into scientific and technical knowledge for more basic studies and for better understanding and utilization by farmers.

MATERIALS AND METHODS

Rice with Tagbak Stalks in Paddy

Experimental Design, Crop Establishment and Management

The study was conducted in the Central Experiment Station of the University of the Philippines Los Baños from August to November 2005 during the wet season and from January to April 2006 during the dry season. Nine plots were laid out where a standing rice crop (PSB RC18) had already been established. There were three treatments and each was replicated three times (Table 1). For treatment 1 during the wet season, seven one-meter tagbak stalks were positioned in eleven rows (3m x 3m distance) throughout the treated area. During the dry season, five one-meter tagbak stalks were placed in fifteen rows at

Table 1.

Treatments Used in the Tagbak Verification Trial. Wet Season 2005 and Dry Season 2006.

[1] Tagbak	1m stalk at 3m x 3m or 1.5m x 1.5m distance, biweekly replacement
[2] Lambda	cyhalothrin at the recommended rate of 25 ml per 16 lL water every week
[3] Control	untreated

1.5m by 1.5m distance (Figure 1) The old, dried stalks were removed at a biweekly interval and replaced with fresh ones gathered from the hilly terrain of Nagcarlan, Laguna. Insecticide application (Treatment 2) was carried out weekly after monitoring the arthropods. Other agronomic practices in transplanted rice, like disease, weed, water and nutrient management, were performed regularly and uniformly in all treatments.

Insect monitoring

The arthropods present in all treatments were monitored and recorded before the initial lambda-cyhalothrin insecticide application in Treatment 2 and weekly thereafter for 6 and 4 consecutive weeks during the wet and dry season, respectively. The presence of stemborer was accounted through their damage, the whitehead, at 11 and 14 weeks after treatment (WAT) during the wet and dry season, respectively. Sampling was done randomly in ten and twenty hills of each plot during the wet and dry seasons, respectively.

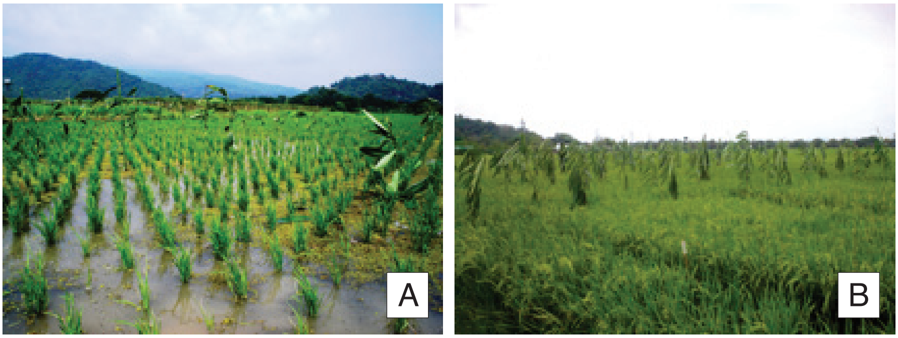

Figure 1. **Rice with tagbak stalks at vegetative stage (A) and fruiting stage (B).**

Statistical Analysis

Treatments were replicated four times using Randomized Complete Block Design (RCBD) and the data were averaged per hill The data was processed using the square root (SQR x + 0.5) or logarithmic (LOG x or x +1) transformation. Differences between the treatments were determined at the 5% level of significance by the Fisher's Least Significant Difference Test.

Cauliflower Intercropped with Celery and Dill

Experimental Design, Crop Establishment and Management

An organic vegetable garden has been cultivated at IPB, UPLB. The area has been maintained for organic vegetable production previously planted with various vegetables intercropped with different herbs such as onion (*Allium cepa*), garlic (*Allium sativum*), oregano (*Origanum vulgare*) and marigolds (*Tagetes* sp.). The pest and natural enemies population was monitored in cauliflower (*Brassica oleracea*) intercropped with celery (*Apium graveolens*) and dill (*Anethum graveolens*) grown in approximately 1000 m^2, without pesticides and synthetic fertilizer in the wet season 2003. Sunflower (*Helianthus annuus*), cosmos (*Cosmos bipinnatus*) and marigolds (*Tagetes* sp.) were maintained as a border. Ten bags of chicken manure were scattered in the area before planting and Hecari, an organic fertilizer was sprayed on the furrows as additional basal fertilizer.

Insect monitoring

Insect pests and natural enemies were monitored using visual and sweeping activities, using an insect net, done on the same day with visual counts done before sweeping. Visual counts were done for 10 plants in half of the plot so as not to disturb the whole plot. Ten sweeps were likewise made in the other half of the plot. Samples from sweeping were sorted, identified and presented as total insect counts. Some sweepings were done in the surrounding, uncultivated area where weeds were present. Aphids were assessed according to the standard aphids assessment: 0 = no aphids, 1 = 1-3 individuals, 3 = 1-3 colonies, 5 = 4-6 colonies, 7 = 7-9 colonies, 9 = more than 9 colonies. (Taylor 1970)

Organic Squash

Experimental Design, Crop Establishment and Management

Organic squash, Sorsogon variety, was grown in the IPB experimental area for seed production purposes in approximately 1000 m^2, without pesticides and synthetic fertilizer on January 25, 2005. This was intercropped with cowpea, which were planted along the rows at a distance of 0.50 m with 2-3 seeds per hill. Yield was not determined as seeds were gathered as planting materials. The area was maintained for about 6 years and was previously planted with various crucifers intercropped with different herbs such as onion, garlic, oregano and marigold for organic vegetable production. Ten bags of chicken manure were scattered in the area before planting. Hecari, a liquefied waste product of Ajinomoto, was sprayed on the furrows as additional basal fertilizer.

To validate organic agriculture practices in squash production in comparison with conventionally grown squash, a second field study was conducted in NCPC, UPLB from March 24 to June 2011. Thirty marigold (*Tagetes erecta*. L.) and 15 lemon grass (*Cymbopogon citratus* (DC) Stapf) plants were grown along the borders of the organic

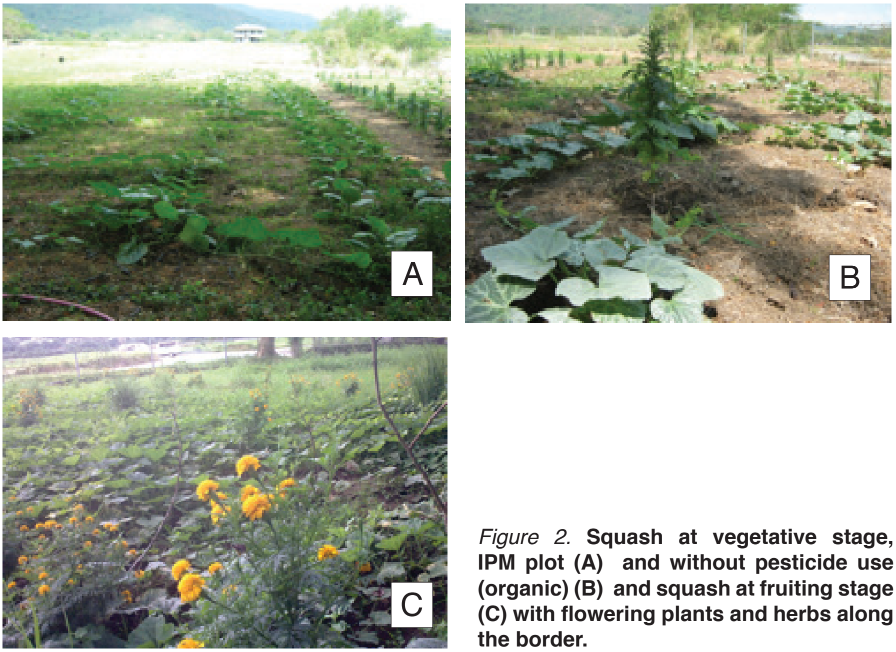

Figure 2. **Squash at vegetative stage, IPM plot (A) and without pesticide use (organic) (B) and squash at fruiting stage (C) with flowering plants and herbs along the border.**

treatment one month before planting squash, to give advance growth to marigold and lemon grass (Figure 2). To control weeds, glyphosate was sprayed a week before planting squash. *Ageratum conyzoides*, *Cleome rutidosperma* (DC), Vernonia cirenea L., cosmos (*Cosmos* sp.) and 3-lobed morning glory (*Ipomoea triloba* L.) were planted in the border simultaneously with squash. A total of 200 m^2 area was used during the conduct of the study. Twenty five squash seedlings were planted per treatment. Two kilograms of chicken manure in treatment 1 (Organic) and 25 grams of complete fertilizer (14-14-14) was applied in treatment 2 (IPM) 15 days after transplanting. Methomyl was applied at 13 days after transplanting at the recommended rate of 2.5 grams per ha. in treatment 2 (IPM). A 3 x 20 meter strip of eggplant served as a barrier between the two treatments. Top dressing was done 35 days after planting using urea (45-0-0) in IPM at 25 grams per hill and 1 kilogram of chicken manure in the organic treatment.

Insect monitoring

Monitoring of insect commenced when the squash canopy was about to close in. The furrows were divided into five (5) rows for observation of pests and natural enemies populations. The rows were further divided into two for visual and sweeping activities. Ten (10) tips of squash (up to ten leaves from the tip) were counted visually in the 2005 study while five plants were sampled per replicate in the 2011 study. Sweeping of the other half was done using 10 sweeps per sample row. The level of aphid infestation was based on a rating scale of 0 (no aphids) to 9 (very heavy/overlapping colonies).

Samples from sweeping were sorted, identified and presented as total insect counts. Visual counts were also tabulated and shown as total of insect pests and natural enemies. Some sweepings were done in the surrounding, uncultivated area where the weeds present were predominantly *Imperata cylindrica, Mimosa pudica, Commelina benghalensis,* and *Rottboellia cochinchinensis* and a mixture of different grasses. On one side, pandan herb mixed with marigold were considered as a refuge of pests and natural enemies. It was swept to compare insect populations with the area where squash was grown.

Population densities were monitored starting two weeks after planting (WAP). Actual count was accomplished at weekly intervals. Treatments were replicated four times using Randomized Complete Block Design (RCBD). Data were analyzed for differences between treatments using F-test at the 5% level of significance.

Table 2.

Total arthropod counts (per plant) in three different treatments and the weeks the arthropods were monitored in trans planted rice during the Wet Season 2005 and the Dry Season 2006.

INSECT PESTS	WET SEASON 2005				DRY SEASON 2006			
	TREATMENTS			Weeks Monitored (in weeks after treatment)	TREATMENTS			Weeks Monitored (in weeks after treatment)
	Tagbak	Lambda cyhalothrin	Control		Tagbak	Lambda cyhalothrin	Control	
1. Green leafhopper	7.27	8.74	13.66	1-6	1.63	1.67	2.89	1-4
2. Brown planthopper	3.27	1.86	1.0	1-6	0.2	0.12	0.5	1-4
3. Whitebacked planthopper	0.64	0.67	0.86	2-4	0.2	0.97	0.36	1-3
4. Stem borer*	9.87	10.3	14.27	11	6.65	4.3	14.08	12
5. Semilooper	0.13	-	-	1, 5 and 6	-	-	-	none
6. Rice bug	-	0.03	-	4	-	-	-	none
7. Cutworm	-	-	0.03	2	-	-	-	none
8. Whorl maggot	-	-	-	none	0.05	0	0.03	1 and 3
9. Leaf folder	-	-	-	none	0.22	0	0	2 and 3
10. Whitefly	-	-	-	none	0	0.87	0.1	1, 3 and 4
11. Zigzag leafhopper	-	-	-	none	0.02	0	0	1
12. Grasshopper	0.53	0.2	0.21	1, 3-6	0	0	0.02	2
13. Cricket	0.03	-	-	6	0.02	0	0	1
Overall Total (*excluding whitehead count*)	**11.87**	**11.57**	**15.76**		**2.34**	**3.63**	**3.90**	

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Table 2. (Continued...)

Total arthropod counts (per plant) in three different treatments and the weeks the arthropods were monitored in trans planted rice during the Wet Season 2005 and the Dry Season 2006.

INSECT PESTS	**WET SEASON 2005**				**DRY SEASON 2006**			
	TREATMENTS			**Weeks Monitored (in weeks after treatment)**	**TREATMENTS**			**Weeks Monitored (in weeks after treatment)**
	Tagbak	**Lambda cyhalothrin**	**Control**		**Tagbak**	**Lambda cyhalothrin**	**Control**	
BENEFICIAL ARTHROPODS								
1. Spider	13.24	4.56	7.13	1-6	1.33	1.04	2.53	1-4
2. Coccinelid beetle	0.52	1.43	1.86	1-6	0.32	0.09	0.34	1-4
3. Cyrtorhinus	0.3	0.74	0.23	2-6	0.22	0.98	0.28	2-4
4. Damselfly	0.17	0.1	0.1	2, 3 and 6	0.02	0	0	1
5. Wasp	0.03	0.13	0.1	6	0	0	0.02	4
6. Ophionea ground beetle	0.13	-	-	6	0.08	0.02	0.2	1-4
7. Dragonfly	0.03	-	-	6	0.02	0.05	0.1	3 and 4
8. Millipede	-	0.07	0.07	3	-	-	-	-
9. Tachinid fly	-	-	0.17	3	-	-	-	-
10. Mirid bug	-	-	-	none	0.31	0.4	0.37	3 and 4
11. Earwig	-	-	-	none	0	0.02	0	4
Overall Total	**14.42**	**7.03**	**9.66**		**2.30**	**2.6**	**3.86**	

*Counted as whiteheads

RESULTS AND DISCUSSION

Rice with Tagbak Stalks in Paddy

Farmers claim that the use of tagbak stalks staked in transplanted rice paddies repel stemborer, whorl maggot and the flying insect pests. Our field monitoring involved population counts of arthropods.

Effect on the insect pests

There were 18 and 19 arthropods recorded in all three treatments, with seven and eight insect pests during the wet and dry seasons, respectively (Table 2). Only four insect pests were common during the two seasons, green leafhopper (GLH), brown planthopper (BPH), whitebacked planthopper (WPH) and stemborer. Three insect pests (i.e. semilooper, rice bug and cutworm) were found during the wet season only, while four (i.e whorl maggot, leaf folder, whitefly and zigzag leafhopper) during the dry season only. Although it was observed that there were less number of insect pests during the dry season compared to the wet season, the tagbak treatment consistently had the least total count of insects for both cropping seasons. (Table 2).

GLH (not considering the whitehead) had the highest count in all three treatments during both seasons (Table 2). During the wet season, GLH was significantly controlled by the tagbak treatment by 47% as against the control and by 9% when compared with the chemical treatment. Significant reduction was noted in the same treatment during the dry season, 42% and 4% lower than the control and the chemical treatment, respectively.

Whorl maggot was not observed during the wet season, but was counted only at 1 and 3 WAT in the dry season (Table 2). At one WAT, whorl maggots were significantly higher in tagbak treatment than control; none were observed in lambda-cyhalothrin treatment. However, tagbak treatment was statistically the same as control at 3 WAT (Table 3).

In addition, the whitehead damage caused by stemborer, was lowest in the tagbak treatment when monitored at 11 WAT when it is expected to occur (Table 4), however, the differences between treatments were not significant.

Table 3.

Weekly Counts[1] (per plant) of Different Arthropods in Transplanted Rice During the Wet Season 2005.

TREATMENTS	GREEN LEAFHOPPER Weeks After Treatment						BROWN PLANTHOPPER Weeks After Treatment						ALL INSECT PESTS Weeks After Treatment					
	1	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
1. Tagbak	1.37a	2.03b	1.93b	1.37b	0.5c	0.07c	1.77a	0.03b	0b	0b	1.3a	0.17a	3.17a	2.23b	2.4ab	1.37a	1.87a	0.27a
2. Lambda cyhalothrin	2.1a	1.6b	1.07b	2.07a	1.5b	0.4a	1.3ab	0.23a	0.03a	0b	0.1b	0.23a	3.37a	2.13b	1.47b	2.1a	1.67a	0.63a
3. Control	2.33a	4.73a	2.5a	1.97a	1.9a	0.23b	0.7b	0.1b	0b	0.03a	0.1b	0.07b	3.03a	4.99a	3.2a	2.03a	2.0a	0.3a

TREATMENTS	SPIDER Weeks After Treatment						COCCINELID BEETLE Weeks After Treatment						ALL BENEFICIALS Weeks After Treatment					
	1	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
1. Tagbak	2.1a	2.3a	0.47b	0.87a	4.3a	3.2a	0.03a	0.03b	0.03b	0.13a	0.17b	0.13b	2.2a	2.4a	0.8a	1.03a	4.57a	3.98a
2. Lambda cyhalothrin	0.53b	1.73a	0.73ab	0.2b	1.3b	0.07c	0a	0.30a	0.37a	0.23a	0.10b	0.43a	0.53b	2.13a	1.27a	0.5a	1.6b	1.2a
3. Control	0.73b	1.63a	1.5a	0.7ab	1.1c	1.47b	0.03a	0.23ab	0.30a	0.30a	0.57a	0.43a	0.76b	1.86a	2.14a	1.17a	1.74b	2.2a

[1] Means in a column followed by the same letter are not significantly different at the 5% level of significance by Fisher's Least Significant Difference Test.

Table 4.

Mean Whitehead Counts (per plant) at 11 WAT in Transplanted Rice During the Wet Season 2005.

TREATMENTS	MEAN[1]
1. Tagbak	9.87a
2. Lambda cyhalothrin	10.03a
3. Control	14.27a
cv (%) = 17.2	

[1] Means in a column followed by the same letter are not significantly different at the 5% level of significance by Fisher's Least Significant Difference Test.

Effect on the beneficial arthropods

Eleven beneficial arthropods were monitored during both cropping seasons in all three treatments (i.e. spiders, coccinelid beetles, *Ophionea* ground beetles, *Cyrtorhinus*, dragonflies, damselflies, grasshoppers and wasps). Millipede and *Tachinid* flies were only observed during the wet season while mirid bugs, crickets and earwigs only during the dry season. The tagbak treatment had the most kinds (9) of beneficial arthropods or an average of about 15 per plant while the chemical treatment had the least (7) numbers reflecting an average count of 7 per plant which was lesser than counts on control plots (10 per plant) in the wet season. Spiders were the most predominant beneficial arthropod followed by coccinelid beetles throughout the 14 weeks period of data gathering. The tagbak treatment had the highest number of beneficials for the wet season (Table 2). Enhanced natural enemy abundance has been reported on organic rice systems (Hesler et al 1993), tomato (Drinkwater et al, 1995) and apple orchards (Wyss et al, 1995).

The weekly count of the first two most abundant insect pests and beneficial arthropods during the wet season are presented in Table 3. Green leafhopper count, at 1 week after treatment (WAT), was statistically the same in all treatments. At 2 and 3 WAT, significant reductions from those of the control were noted in the tagbak and lambda-cyhalothrin treatments for both seasons (Tables 3 and 5). From 4 to 6 WAT, green leafhopper became significantly the least in the tagbak treatment (Table 3). The treatments did not establish a reduction in brown plant hopper populations. Tagbak caused no difference from the control at 2 and 3 WAT, a significantly greater

Table 5.

Weekly Counts[1] (per plant) of Different Arthropods in Transplanted Rice During the Dry Season 2006.

TREATMENTS	GREEN LEAFHOPPERS				BROWN PLANTHOPPERS				ALL INSECT PESTS			
	Weeks After Treatment				**Weeks After Treatment**				**Weeks After Treatment**			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
1. Tagbak	0.37 b	0.95 a	0.18 b	0.13 b	0.05 b	0.08 b	0.07 a	0 b	0.57a	1.13a	0.49a	0.13a
2. Lambda cyhalothrin	0.37 b	0.5 b	0.38 ab	0.42 a	0.10 ab	0.02 b	0 b	0 b	0.72a	1.48a	0.90a	0.52a
3. Control	0.82 a	0.72 ab	0.83 a	0.52 a	0.13 a	0.25 a	0.05 a	0.07 a	1.23a	1.05a	1.01a	0.59a

TREATMENTS	SPIDERS				COCCINELID BEETLES				ALL BENEFICIALS			
	Weeks After Treatment				**Weeks After Treatment**				**Weeks After Treatment**			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
1. Tagbak	0.05 b	0.08 b	0.07 a	0 b	0 a	0.10	0.12	0.10	0.42b	0.75a	0.51a	0.64b
2. Lambda cyhalothrin	0.10 ab	0.02 b	0 b	0 b	0.02 a	0	0.07	0	0.87ab	0.14b	0.52a	1.07ab
3. Control	0.13 a	0.25 a	0.05 a	0.07 a	0.02 a	0.10	0.07	0.15	1.19a	0.52ab	0.75a	1.40a

[1] Means in a column followed by the same letter are not significantly different at the 5% level of significance by Fisher's Least Significant Difference Test.

Table 6.

Counts and Differences Between the Insect Pests and Beneficial Arthropods in Transplanted Rice During the Wet Season 2005.

TREATMENTS	INSECT PESTS		BENEFICIAL ARTHROPOD		
	Counts (per plant)	Reduction (%)	Counts (per plant)	Difference (%) From the Control	Difference (%) From the Other Treatment
1. Tagbak	11.31	27	14.8	50↑*	97↑
2. Lambda -cyhalothrin	10.57	32	7.5	24↓	-
3. Control	15.55	-	9.87	-	-

*↑Means higher than, ↓ means lower than.

count than the control at 1, 5 and 6 WAT and a significantly lower count than the control at 4 WAT. Lambda cyhalothrin caused no difference in the brown plant hopper count when compared with tagbak and control at 1 WAT, a significantly higher count than tagbak and control at 2 and 3 WAT, a significantly lower count than the control but the same as tagbak at 4 WAT, a significantly lower count than tagbak but the same as the control at 5 WAT and a significantly higher count than the control and the same as tagbak treatment at 6 WAT.

Spider counts were higher in the tagbak treatment compared with those of control and lambda cyhalothrin at 1, 2, 4, 5, and 6 WAT during the wet season (Table 3). It peaked in the tagbak treatment at 2 WAT. Coccinelid beetle count was highest in the control followed by lambda cyhalothrin and tagbak treatments. The use of tagbak reduced the insect pest population by 27% and harbored the highest number of beneficial arthropods, 33% and 49% higher than that of the control and lambda cyhalothrin treatments, respectively. This is consistent with observed enhanced beneficial populations in soybeans (Altieri, et al 1981) and corn (Turlings et al, 1990). Lambda-cyhalothrin reduced the population of the target organisms the most (32%) but, also destroyed the beneficial arthropods that parasitize or prey on those insect pests (Table 6).

Effect on Yield

Yield during the dry season was computed at 5.8 tons ha^{-1} in the

Table 7.

Arthropod diversity in organically grown cauliflower intercropped with dill and celery at head development stage, based on actual count and sweep net monitoring methods, IPB, UPLB.

	Cauliflower + Dill + Celery			
	1 week	**2 weeks**	**3 weeks**	**4 weeks**
Insect Pests				
Homoptera				
Whitefly				
Bemesia tabaci (Gennadius)	47	359	45	42
Coleoptera				
Fleabeetle				
Phyllotreta striolata (Fabricius)	0	0	1	1
Lepidoptera				
Cutworm, larvae				
Spodoptera litura	8	28	461	76
Semi-looper				
Trichoplusia ni	2	0	0	0
Diamond back moth				
Plutella xylostella (Linnaeus)	0	4	0	2
Cabbage moth, larvae				
Mamestra brassicae	0	110	41	16
Hemiptera				
Aphids				
Aphis gossypii Glover	0	2	2.5	3
Leafhoppers	1	0	0	2
Ichneumonid	0	0	1	0
Natural Enemies				
Coccinellids	0	0	0	0
Bees	0	0	1	0
Spiders	5	2	1	7
Ants	0	0	1	0
Pentatomids	1	0	0	0

Aphid data is based on a rating scale (0—no aphids; 1—few individuals; 3—one to three colonies; 5—four to six colonies; 7—seven or more distinct colonies; 9—very heavy colonies with overlaps).

tagbak treatment and 7.3 tons per hectare in the chemical treatment, 19% and 36% higher than that of the control, respectively.

Intercropping effects, which lends associational resistance, is demonstrated in terms of suppression of oviposition and larval populations of various pests (Theunissen et al 1995; Perrin and Philips 1978; Togni et al, 2010). Mechanisms accounting for herbivore responses to plant mixtures in diversified agricultural systems include reduced colonization, reduced adult tenure time in the marketable crop, and oviposition interference (Hooks and Johnson, 2003). The reduction in the insect pest counts are most likely affected by the volatile chemicals emitted by the stalks in the atmosphere. Regulation of insect populations may be due to complex interacting factors such as associational resistance (Root, 1973; Buranday and Raros, 1975), reduction of crop apparency (Feeny, 1976).

The insecticidal activity of *A. elegans* has not been demonstrated despite extensive literature search. It appears that the practice of using tagbak as an insect pest management strategy may be undocumented. While, tagbak is not intercropped with rice, the volatile organic chemicals emitted from the stalks may cause changes in the chemical cues that insects can perceive in this particular ecosytem. Our data suggests that chemicals emitted by tagbak affect insect behavior with the ultimate result of reducing pest populations while increasing natural enemy populations. Repellency of volatile plant chemicals have also been observed for certain insects (Tawatsin et al 2006; Garboui et al 2007). The pungent principal of tagbak stalks could be due to limonene, α-pinene, and β-pinene, chemicals found in its essential oil (Oliveros and Bruce, 1991).

Cauliflower Intercropped with Celery and Dill

A mixed herb (dill and celery)-cauliflower cropping system with sunflower, cosmos and marigold borders, negatively affected the major insect pests of cauliflower such as diamond back moth and cabbage moth (Table 7). During the first 6 weeks vegetative and heading stage, there were no insect pests observed. Interestingly, diamond-back moth counts were very low for the 4 weeks observation period.

During the first week at head development stage, only whiteflies, leafhoppers and cutworms were observed in cauliflower. No natural enemies were counted. In the second week, whiteflies were more predominant than in the first week of counting. Cabbage moths were also observed. Cutworm larvae followed by whitefly, cabbage moth larvae and aphids were the dominant insect pests on the third week. In the last week of counting, cutworm was still the dominant insect followed by whitefly, cabbage moth and leafhoppers.

The intercropped herbs (celery and dill) and border herbs (marigold, lemon grass and basil) did not reduce the cutworm population. Insect counts showed heavy infestation by whiteflies and cutworm during the head development and maturity stages (2-3 weeks) although it was observed that the counts dropped significantly at 3-4 weeks. Cabbage moth, aphids, and some spiders were also observed. Natural enemies were very low during the season but spiders were observed on cauliflower.

Intercropping effects in terms of suppression of oviposition and larval populations of various pests have been demonstrated by other researchers. The quality of the cabbages intercropped with clovers lead to a better profits compared to the monocropped cabbage crop (Theunissen et al. 1995). Radish yield was higher when intercropped with lettuce (Resende et al. 2001). Plant volatiles were major factors in *P. xylostella* host preference. (Badenes-Perez et al., 2004). *P. xylostella* laid nearly twice as many eggs per plant in the high planting densities of glossy collards intercropped with yellow rocket (Badenes-Perez et al. 2005).

The presence of wildflowers in the borders can serve as nectar sources for the parasitoid *Diadegma insulare* (Hymenoptera: Ichneumonidae), a parasitoid of diamond back moth (Idris and Grafius, 1995). Crop and noncrop habitats provide resources to natural enemies either directly through floral nectar and pollen, indirectly by increased host or prey availability, or through emergent properties of the habitat such as by moderating the microclimate (Landis et al. 2005).

Arthropod Populations in Organic Squash

A. First Cropping 2005, IPB, UPLB

During the vegetative stage (33-47 DAP), the dominant pests were whiteflies, squash beetles, pentatomid bugs, melon moth larvae, leafhoppers and flea beetles (Table 8). Thrips were monitored only at 33 DAP. At the flowering and fruiting stages (61-75 DAP) pentatomid bugs were still the dominant pests followed by whiteflies which declined at 68 DAP and increased again at 75 DAP. Other pests

Table 8.

Arthropod Diversity in Organically Grown Squash, Intercropped With Cowpea, Based on Actual Count and Sweep Net Monitoring Methods, IPB, UPLB, January-April 2005.

Arthropod	VEGETATIVE STAGE			REPRODUCTIVE STAGE				
	Days After Planting (DAP)							
	33	**40**	**47**	**54**	**61**	**68**	**75**	**Total**
A. Pests								
HEMIPTERA								
Aphids (*Aphis gossypii* Glover)	2.2	1.0	3.5	1.0	1.0	1.0	3.0	12.7
Leafhoppers (*Empoasca ricei* Dworakowska and Pawar)	4	0	0	18	2	11	3	38.0
Pentatomids, various species	7	21	10	38	87	43	15	221.0
HOMOPTERA								
White fly (*Bemesia tabaci* Gennadius)	17	7	26	42	28	13	46	179.0
Melonworm moth larvae (*Diaphania indica* Saunders)	7	8	1	5	4	0	1	26.0
COLEOPTERA								
Squash Beetle (*Aulacophora indica* Gmelin)	13	9	6	11	4	3	4	50.0
Flea Beetle (*Phyllotreta striolata* Fabricius)	0	2	3	10	3	5	4	27.0
DIPTERA								
Fruit fly	0	0	0	0	0	3	2	5.0
THYSANOPTERA								
Thrips, various species	3	0	0	0	0	0	0	3.0
B. Natural enemies								
ARANEAE								
Spiders, various species	3	4	3	14	17	29	12	82.0
COLEOPTERA								
Mirid bug (*Cyrtorhinus lividipennis* Reuter)	0	0	1	7	2	10	7	27.0
Coccinelid (*Menochilus sexmaculatus* Fabricius)	0	0	1	0	0	1	0	2.0
ODONATA								
Dragon fly, various species	1	1	2	0	0	0	0	4.0

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Table 8. (Continued...)

Arthropod Diversity in Organically Grown Squash, Intercropped With Cowpea, Based on Actual Count and Sweep Net Monitoring Methods, IPB, UPLB, January-April 2005.

Arthropod	VEGETATIVE STAGE			REPRODUCTIVE STAGE				
	Days After Planting (DAP)							
	33	**40**	**47**	**54**	**61**	**68**	**75**	**Total**
HYMENOPTERA								
Ants (*Solenopsis geminata* Fabricius)	0	0	0	6	5	19	5	35.0
Bumble bees, various species	0	4	0	1	7	0	0	12.0
Hymenopteran, various species	2	2	5	0	0	0	0	9.0
Hemiptera, various species	3	2	5	0	0	0	0	10.0
Diptera, ,various species	2	1	5	12	15	7	6	48.0
C. Refugia								
DIPTERA								
Fruit fly, various species	-	-	-	-	-	0	2	2.0
Diptera, various species	-	-	-	-	-	0	8	8.0
COLEOPTERA								
Flea Beetle (*Phyllotreta striolata* Fabricius)	-	-	-	-	-	3	1	4.0
Squash Beetle (*Aulacophora indica* Gmelin)	-	-	-	-	-	2	0	2.0
HEMIPTERA								
Pentatomid, various species	-	-	-	-	-	16	5	21.0
Leafhoppers (*Empoasca ricei* Dworakowska and Pawar)	-	-	-	-	-	2	1	3.0
ARANEAE								
Spiders, various species	-	-	-	-	-	12	11	23.0
HYMENOPTERA								
Ants (*Solenopsis geminata* Fabricius)	-	-	-	-	-	3	6	9.0

Aphid data is based on a rating scale (0—no aphids; 1—few individuals; 3—one to three colonies; 5—four to six colonies; 7—seven or more distinct colonies; 9—very heavy colonies with overlaps)

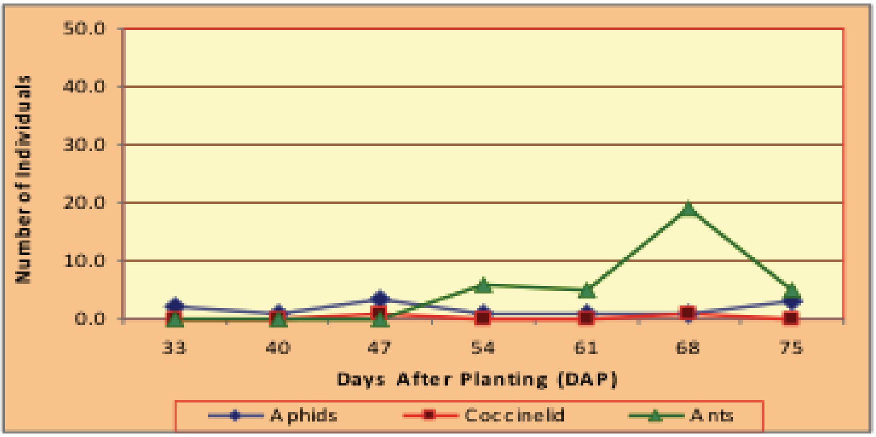

Figure 3. **Weekly counts of aphids vs coccinelids and ants in organic squash field trial, 2005.**

remained visible during this stage but populations were low.

Natural enemies like spiders, ants, bumble bees, and mirid bugs were low during 33-47 DAP (Table 8), but increased at 54 DAP, indicating that as the crop approaches the reproductive stages, the natural enemy populations begin to rise. During the flowering and fruiting stages, the natural enemies (spiders, mirid bugs and ants) counts increased and peaked at 68 DAP.

The level of aphid infestation, ranged from 1 (few individuals) to 3.5 (1-3 colonies) (Figure 3). There is a decline of the aphid population at 54 DAP, which coincided with the initial appearance of ants. The ants are apparently influential in the recovery of the aphid population at 68 DAP. However, it was observed that aphid population declined at 75 DAP while ant population increased slightly. Coccinellid beetle predators apparently did not play a major role in affecting the population fluctuations of aphids as the population density of the predator remained negligible (0-1 individuals) throughout the observation period.

Leafhoppers were affected by the presence of spiders during the 40 and 47 DAP period (Figure 4). From 54 DAP onwards (reproductive stages), there was a build- up of aphid populations which caused the decline in leafhoppers populations. Spiders did not affect the whiteflies population in the vegetative stage (Figure 5). Low levels of spiders caused whiteflies to surge up, and conversely, an increase of spiders at 68 DAP resulted in a decline in whiteflies populations Hymenopterans do not affect populations of whiteflies

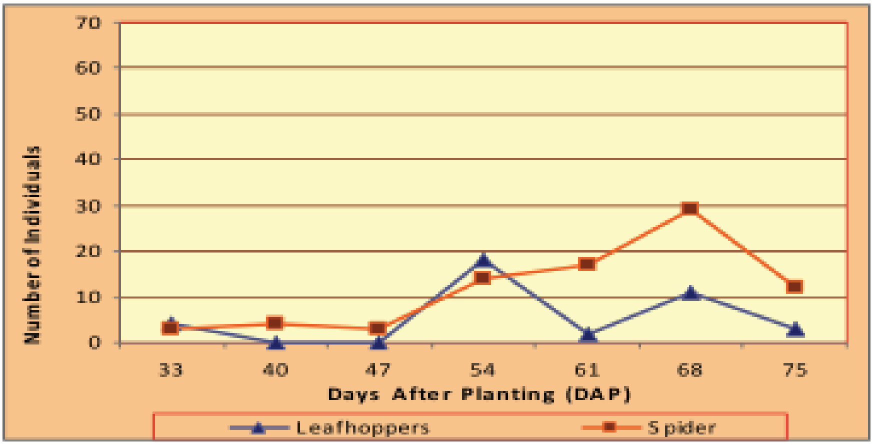

Figure 4. **Weekly counts of leafhopper vs. spiders in organic squash field trial, 2005.**

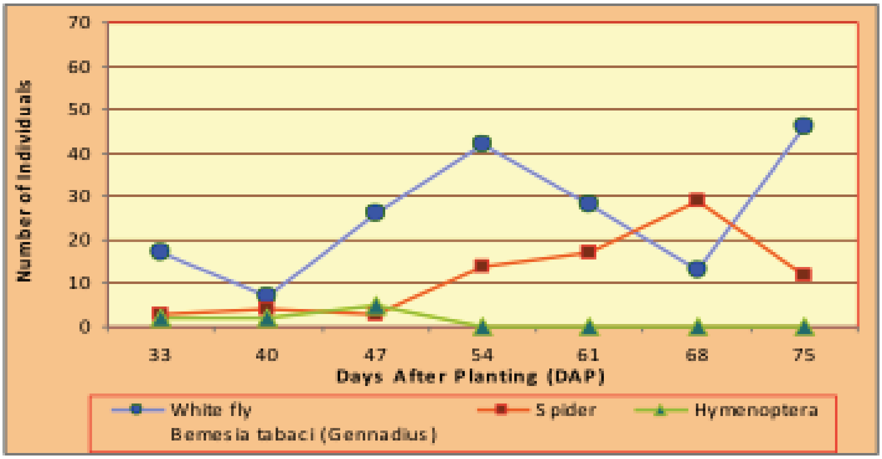

Figure 5. **Weekly counts of whitefly vs. spiders and hymenoptera in organic squash field trial, 2005.**

as it was monitored in low populations. During the vegetative stage, squash beetle populations were not affected by the presence of very low populations of spiders (Figure 6). However, during the flowering and fruiting stages, squash beetle declined in numbers as the spiders increased. This indicates that spider per se, is not a deterrent to the squash beetle population. The decline of the squash beetle population during the latter stages could be attributed to the lack of younger leaves which the insect prefers. There is a direct relationship between pentatomid pests and spiders in organic squash. However, due to the high populations of the pentatomid pest, spiders are not effective

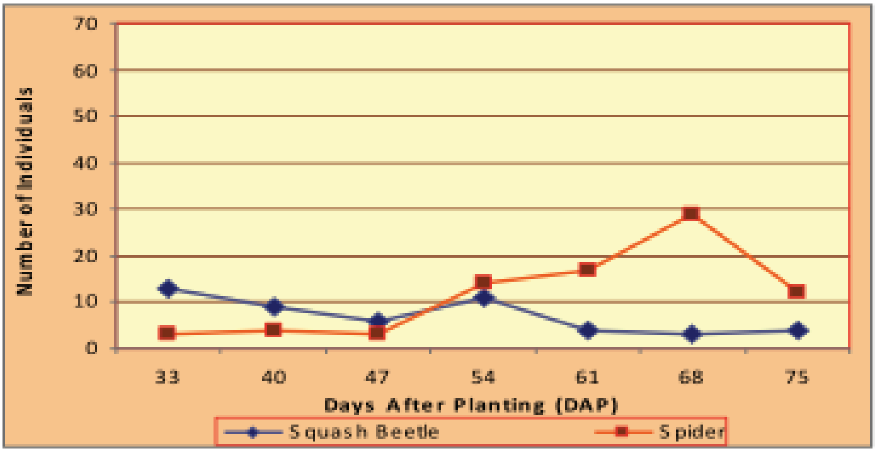

Figure 6. **Weekly counts of squash beetle vs. spiders in organic squash field trial, 2005.**

biocontrol agents against it (Table 8).

The surrounding border of the squash area served as refugia for pentatomid bug while other pests like leafhopper, squash beetle, flea beetle, grasshopper and fruit fly larvae occurred at low populations. The pests were swept in *Roettboellia cochinchinensis* (itch grass), *Imperata cylindrica* (cogon), *Mimosa pudica* (sensitive plant), *Commelina* spp. and a mixture of different grasses. Of the natural enemies only spider, ants, and some dipterans were swept in the surrounding area. Dipterans were observed at 75 DAP when the crop was at fruiting stage (Table 8). Floral volatiles are known to attract both floral herbivores and pollinators (Theis 2006).

The organic squash showed 90 or more percent of mosaic like viruses during the fruiting stage. The viruses were not identified but it might be transmitted by insects or some way of transmittal like mechanical means.

Weeds were not a constraint during seedling stage even though the area was unweeded; it is probably due to the polyethylene plastic mulch on the furrows. It becomes critical when the crop is about to close in up to fruiting stage. The weeds present in the area were *Cyperus rotundus, Cyperus iria, Digitaria setigera, Amaranthus spinosus, Trianthema portulacastrum, Celosia argentea, Eclipta alba, Synedrilla nodiflora, Cleome rutidosperma, Euphorbia hirta, Mimosa pudica, Bracharia mutica, Eluesine indica, Poa annua, Physalis angulata,* and *Dactelactenium aegyptium*.

Table 9.

Arthropod Diversity in Organic and IPM Plots Based on Actual Count and Sweep Net Monitoring Methods. NCPC, March-June 2011.

Arthropod	Treatments	VEGETATIVE STAGE				REPRODUCTIVE STAGE						Total
		Days After Planting (DAP)										
		27	33	40	47	54	60	68	75	83	89	
A. Pests												
HOMOPTERA												
White fly	Organic	14	16	4	11	48	50	59	78	43	—	323 a
Bemisia tabaci (Gennadius)	IPM	20	33	8	12	31	38	48	84	39	—	313 a
LEPIDOPTERA												
Cutworm	Organic	0	0	0	0	0	0	0	0	0	—	0 a
Spodoptera litura (Fabricius)	IPM	0	0	0	0	2	0	0	0	0	—	2 a
Cutworm	Organic	0	0	0	0	0	0	0	0	0	—	0 a
(egg mass)	IPM	0	0	0	0	1	0	0	0	0	—	1 a
Melonworm moth	Organic	24	4	1	0	0	0	0	0	0	—	29 a
Diaphania indica (Saunders)	IPM	15	6	0	0	0	0	0	0	0	—	21 a
COLEOPTERA												
Flea Beetle	Organic	0	0	0	0	1	1	1	0	0	0	3 a
Phyllotreta striolata (Fabricius)	IPM	0	0	1	1	0	1	1	1	0	0	5 a
Squash Beetle	Organic	3	4	4	5	99	7	12	22	12	7	175 a
Aulacophora indica (Gmelin)	IPM	9	2	2	4	5	6	8	10	11	5	62 b
HEMIPTERA												
Leafhoppers	Organic	2	0	1	3	2	1	0	0	0	0	9 a
Empoasca ricei Dworakowska and Pawar	IPM	3	0	4	3	6	2	1	0	0	0	19 a
Aphids	Organic	3	6	0	0	0	0	0	0	0	—	9 a
Aphis gossypi Glover	IPM	8	3	0	0	0	0	0	0	0	—	11 a
ORTHOPTERA												
Katydid	Organic	0	0	0	1	0	0	0	0	0	0	1 a
Phaneroptera furcifera Stål	IPM	0	0	0	0	0	0	0	0	0	0	0 a

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Table 9. (Continued...)

Arthropod Diversity in Organic and IPM Plots Based on Actual Count and Sweep Net Monitoring Methods. NCPC, March-June 2011.

Arthropod	Treatments	VEGETATIVE STAGE					REPRODUCTIVE STAGE					Total	
		Days After Planting (DAP)											
		27	33	40	47	54	60	68	75	83	89		
B. Natural enemies													
ARANEAE													
Spiders, various species	Organic	1	1	0	3	3	2	4	0	1	0	15	a
	IPM	2	0	2	0	6	1	3	0	0	1	15	a
DIPTERA													
Wasp	Organic	0	0	0	0	0	1	0	0	0	0	1	a
	IPM	0	0	0	0	3	0	0	0	0	0	3	b
Diptera, various species	Organic	0	0	6	2	2	3	2	1	2	0	18	a
	IPM	0	0	0	1	1	1	2	1	0	0	6	b
ODONATA													
Damsel fly, various species	Organic	0	0	0	0	1	0	0	0	0	0	1	a
	IPM	0	0	0	0	0	0	0	0	0	0	0	a
HYMENOPTERA													
Ants	Organic	0	0	0	0	0	0	0	0	0	0	0	a
Solenopsis geminata (Fabricius)	IPM	0	0	0	1	1	0	0	0	0	0	2	a
Cotesia sp.	Organic	0	0	0	0	1	0	0	0	0	0	1	a
	IPM	0	0	0	0	0	0	0	0	0	0	0	a
Hymenoptera, various species	Organic	0	0	0	2	1	2	1	0	1	1	8	a
	IPM	0	0	1	0	0	0	0	1	1	1	4	a
COLEOPTERA													
Ladybird Beetle	Organic	0	1	0	0	0	0	0	0	0	—	1	a
Menochilus sexmaculatus Fabricius	IPM	0	0	0	0	0	0	0	0	1	—	1	a
Mirid bug	Organic	0	3	1	1	2	0	0	0	0	0	7	a
Cyrtorhinus lividipennis Reuter	IPM	0	1	0	0	2	0	0	0	0	0	3	a

For each arthropod, treatments having the same letter are not significantly different based on F-test (F Prob. <= 0.05)

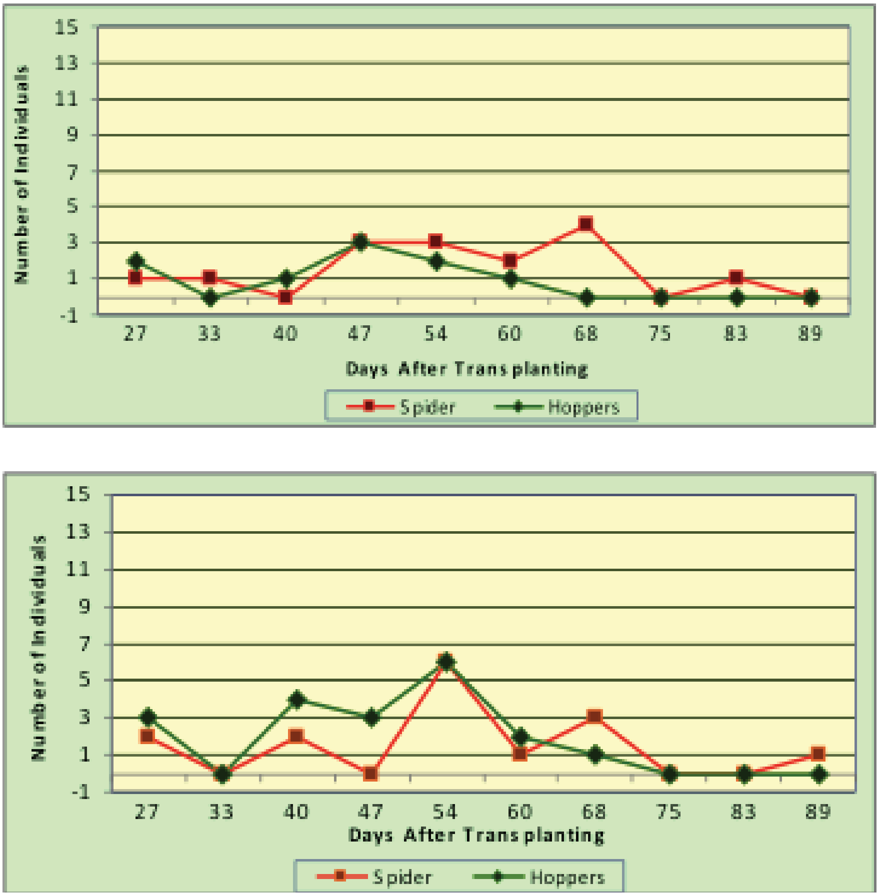

Figure 7. **Weekly counts of leafhoppers vs spiders in squash field trial(A- Organic; B-IPM), 2011.**

B. Second cropping, NCPC, UPLB 2011

A total of 18 different species of arthropods were observed in the experimental plots (Table 9). Except for squash beetles, all other pest species did not differ significantly in terms of total population in both the Organic and IPM plots. Cutworm was not recorded to attack organic squash plants; it only attacked IPM plants. Aphids and Diaphania were more numerous during the vegetative stage while squash beetle peaked at the reproductive stage. Whiteflies were always present in every monitoring period (Table 9). Ants were not observed in organic plots while Cotesia, katydid and damsel fly

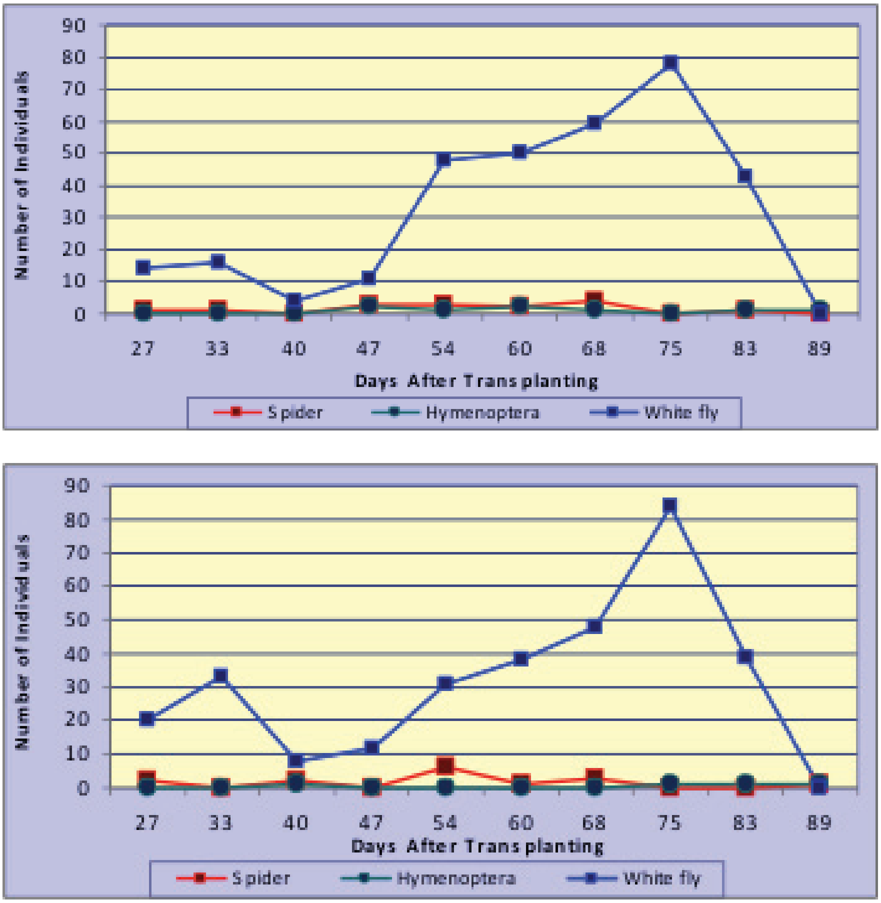

Figure 8. **Weekly counts of whitefly vs. spiders and hymenoptera in squash field trial (A- Organic; B- IPM), 2011.**

were absent in the IPM plots. In addition, significantly higher diptera populations were observed in organic than in IPM treatment plots. This is an indication of greater diversity of beneficial under organic culture. Notable also were the numerically higher number of mirid bugs and hymenoptera individuals in the organic plots. The aphid population occurred more during the vegetative stage of the squash plants. There is no indication of direct relationships between the aphid, ant or ladybird beetle population fluctuations.

In organic squash, there is an apparent earlier control of leafhopper populations by spiders from 47 DAP onwards (Figure 7a) than in the IPM plots (from 68 DAP) (Figure 7b). Spiders are predators and are

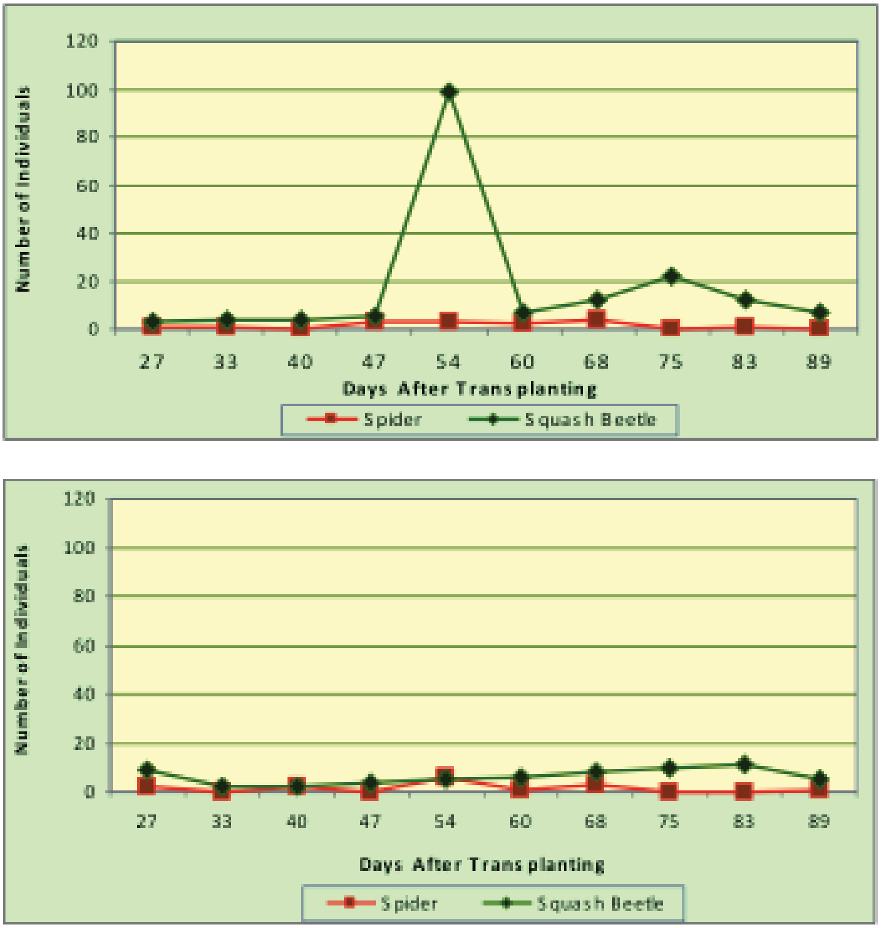

Figure 9. **Weekly counts of squash beetles vs. spiders (A- Organic; B- IPM) in organic squash field trial, 2011.**

able to reduce leafhopper populations (Kiritani et al, 1972 Riechert and Bishop, 1990). Insecticide spraying in the IPM plot at 13 days after transplanting could have reduced spider populations making the predator unable to rebound in sufficient numbers to inflict sufficient control against the pest.

Spiders and hymenoptera did not affect the whiteflies population (Figure 8a and 8b). Low count of spiders and hymenoptera compared with the high whitefly population counts in all monitoring periods indicates that they are not effective during high population surges or do not attack the pest at all. Spiders were not able to prey sufficiently on squash beetle individuals in organic squash plants (Figure 9a). A high spike of squash beetle population density at 54 DAP signified that under favorable conditions, spiders cannot effectively check the squash beetle population increase. Under IPM plot conditions, however, squash beetle populations hover below the 20 individual mark- fluctuating in a similar manner with the spider population (Figure 9b).

Yield

Although our initial results show the organic plot producing more squash fruits than the IPM plot, the total yield was not computed as heavy rains in the later part of the season destroyed the fruits.

Our results are very similar to the pest populations observed in a previous study on squash which looked at the impact of intercropping squash with sorghum-sudangrass. This cropping system resulted in spill-over of natural enemies, predatory Coleoptera, into the neighboring crop squash. Border crops did not influence the movement of thrips and whiteflies, however in situ aphid counts were lower on squash bordered by sorghum-sudangrass than in the control. Flea beetles (*Altica* spp.) were consistently most abundant in the bare ground border, but many arthropod groups were unaffected by the treatment. None of the border treatments could prevent a heavy infestation of melonworm (*Diaphania hyalinata* L.) (HansPetersen et al. 2010).

CONCLUSIONS

Our results validate the farmer practice of using tagbak stalks in rice production to manage insect pests for integrated pest management (IPM) in low input or organic rice production..

Intercropping of herbs and vegetables can reduce some insect pest populations in the field. We demonstrated that a mixture of dill, celery and lemon grass grown together with cauliflower could result in very low diamond back moth populations in the field. However, this cropping system was not adequate to address the cutworm population. The results support the view that greater diversity of beneficial arthropods can reduce certain pest populations. Spiders and ants play an important role in the control of leafhopper and aphid populations.

There is a need to validate the results in the mixed herb-vegetable and organic squash cropping systems in field trials. The usefulness of incorporating biological control measures, into integrated pest management systems, will surely benefit farmers through reduced dependence on commercial inputs.

ACKNOWLEDGEMENTS

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