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CONTRASTING ARTHROPOD COMMUNITIES IN WOLFBERRY ORCHARDS OF DIFFERENT MANAGEMENT REGIMES IN NORTHWESTERN CHINA

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The arthropod community structure in wolfberry orchards of different management regimes were monitored from April to August in 2012 at Ningxia Hui Autonomous Region of Northwestern China. The three different management regimes included (1) orchard free of pesticide, (2) organic orchard, and (3) conventional orchard. Totally, 167 species (4 classes, 27 orders, and 76 families) contained 61 natural enemy species and 106 pest species were recorded in the experiment. The species richness of the orchard free of pesticide, organic orchard with biological control and conventional orchard with chemical control was 61, 30 and 23 species, respectively. Moreover, the corresponding coefficients in the orchard free of pesticide, conventional orchard and organic orchard were 0.864, 0.684 and 0.733, respectively. The different modules of pests varied in their responses to environmental factors depending on different feeding types. The linkage between arthropod community and environmental factors indicated that vegetation diversity, plant coverage, pesticide application and irrigation times exerted detectable contrasting effects on arthropod community and population dynamics. Finally, we suggest that habitat management (i.e. increase in plant cover and diversity) may serve as effective tactics for preventing pest population from reaching the economic injury level which minimizing the input of pesticides and fertilizers.
Keywords: Ningxia, wolfberry orchards, arthropod, management regimes, species richness.

INTRODUCTION

Since the late 1990s, land area for organic agriculture has been expanding in response to growing concerns regarding food safety and environmental issues (Willer and Kilcher, 2009). Organic agriculture is defined according to the Organic Foods Production Act as a production system in which famers "respond to site-specific conditions by integrating cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance and preserve biodiversity (USDA National Organic Program, http://www.ams.usda.gov/NOP). With the ever-increasing consumer pressure on reducing the use of pesticides, fertilizers, veterinary medicines and growth promoters in food production systems, the public demand for organic foods continues to increase. As a result, future strong growth in organic agriculture and food production in China is anticipated.

Wolfberry, *Lycium barbarum* L. (*Gouqizi*, *Fructus Lycii*,) is a famous traditional Chinese medicinal herb. This species plays multiple roles in pharmacological and biological functions. For example, wolfberry fruits can be used to produce various types of healthy products and foods, e.g., medicinal beverages and drinks, and healthy dietary soups (Li, 2001). Notably, wolfberry fruits have been widely used as a popular functional food with a large variety of beneficial effects, such as reducing blood glucose and serum lipids, anti-aging, immuno-modulating, anticancer, anti-fatigue, and male fertility-facilitating (Peng *et al*., 2001a, b; Luo *et al*., 2006; Amagase and Nance, 2008; Chang and So, 2008; Niu *et al*., 2008; Chen *et al*., 2009; Ho *et al*., 2010; Li *et al*., 2011; Mao *et al*., 2011). Ningxia province, located in the northwest of China, is the most well-known area for its wolfberry industry. The acreage of wolfberry cultivation in Ningxia province was 2,960,000 ha in 2007, accounting for 30% of the total plantation area of wolfberry in China (data from China Statistical Abstract). However, wolfberry production in Ningxia has long suffered major infestations by many pest species, such as *Neoceratitis asiatica* Becker, *Aceri macrodonis* Keifer and Lema (Microlema) decempunctata Gebler. To date, the *Aphis* sp., *Poratrioza sinica* Yang et Li, *Aceri macrodonis* Keifer and *Jaapiella* sp. Fedotova are also found infesting heavily wolfberry plants in some regions of China (Liu *et al*., 2015). In recent years, the widespread adoption of wolfberry in Ningxia has triggered ecological shifts of arthropod assemblage. To control those pests, the application of chemical pesticides has risen steadily, which has disrupted the trophic links between the pests and their natural enemies. Simultaneously, the accelerating resistance development of pests and the outbreak of some secondary pests (resulted from the extensive use of insecticides) have caused considerable reduction in the yield and quality of wolfberry. Confronted by this challenge, it is necessary to develop scientifically valid and economically acceptable pest management programs due to the increasing costs of developing and registering new classes of insecticides. However, disentangling and ranking the influences of multiple environmental factors on plant- and soil-dwelling arthropod assemblages is the important base and premise of a beginning agro-ecosystem.

The outbreak of pests in wolfberry orchards could considerably reduce the yield and quality of wolfberry and thus threaten the wolfberry industry. To reduce wolfberry plants from being infested by the herbivores, many control methods, such as resistant varieties, agricultural, biological and chemical controls have been developed (Zhao and Liu, 2015). Biological control is an environmentally sound and effective means of reducing or mitigating pests. However, this method has not been adopted by wolfberry growers because it is relatively time-consuming and costly. For farmers, the favorite method for insect pest control is the application of chemical insecticides. However, the frequent use of pesticides can cause severe environmental pollution and the resurgence of herbivores, and reduce the population of natural enemies of herbivores as well (Desneux *et al.,* 2007; Biondi *et al*., 2012). To control insect pests with safe, effective and sustainable strategies encouraging biological control are currently demanded (Ali *et al.,* 2016).

The present study aims to test the hypothesis that the reduction in insecticides use in the organic orchard would not stimulate the population density and diversity of insect pests. For this, field samplings were performed to compare the community characteristics of arthropod in wolfberry orchards of different management regimes, i.e. orchard free of pesticide, organic orchard, and conventional orchard. Overall, this is one of the first studies comparing the arthropod communities in wolfberry orchards of different management regimes.

MATERIALS AND METHODS

***Experimental site and cultivar*:** The experiment was conducted in Ningxia province (longitude: 104°18´-107°39´, latitude: 35°14´-39°23´), located in the northwest mainland of China and at the midstream of the Yellow River.

The wolfberry cultivar, "Ningxia No. 1", was used for the experiment because of its high-yield, high-quality and better adaptability. This cultivar, provided by the Ningxia Academy of Agricultural Sciences, has been approved and planted widespread in Ningxia, Xinjiang, Gansu, Inner Mongolia, Hubei, Shaanxi and other regions. From the orchard field performance, it proved to be susceptible to wolfberry *Aphis* sp., *Jaapiella* sp. and *Aculops lycii* Kuang, and it showed higher resistance towards drought and root rot (Zhao *et al*., 2009).

***Experimental design and arthropod sampling*:** Arthropod samplings were conducted in three types of wolfberry orchards (pesticide free, organic and conventional orchards) from April 3rd to August 21st in 2012 at Research Institute of Ningxia wolfberry (Yinchuan City). All the wolfberry trees were grown with a regular distance (strain in 1 meter, row in 3 meters) for all orchards. The orchard with the first regime, pesticide free orchard, was located in the central experimental orchard of wolfberry at Vegetable Research Institute, Ningxia Academy of Agricultural and Forestry Sciences, China. This orchard type was without any pesticide application and assigned as control. All trees were 6 years old and no pesticide was used. The orchard with second regime, the conventional orchard with chemical control, was located at Yuanlinchang in Yinchuan of Ningxia province. The trees in these orchards were 10 years old. Pests were controlled with pesticides according to local recommendations in which the orchard was located including abamectin, imidacloprid and chlorpyrifos and they were sprayed for 12 times from March to November during the year. The orchard with the third regime, the organic orchard with the organic practices (zero input of chemical fertilizers and any other agrochemicals), was also located at Yuanlinchang in Yinchuan of Ningxia province. The trees were 7 years old.

The arthropods were surveyed in each experimental unit using Chessboard-like sampling method at one week interval for a total of 21 dates from April 3rd to August 21st in 2012. In each site, five randomly selected spots were used at a distance of more than 10m away from orchard margins to avoid edge effects. For sampling, each tree was divided into five directions; the east, the south, the west, the north and the middle. For each direction, a 40cm long branch was randomly selected. The identity and abundance of common species of flightless arthropod were recorded visually while rare species were kept for further identification in the laboratory. Larvae found in orchards were kept in vial individually and kept at room temperature to wait their adult emergence for further identification. The flying insects were sampled by 50 random sweeping of insect catching nets. The parasitoids abundances were estimated according to the parasitic rate on pests. For mites, a representative branch longer than 40cm for each direction was collected and brought back to the laboratory, and the number of galls, *Aculops lycii* Kuang, and predatory mites were counted under the microscope. For spiders, a representative branch longer than 40cm for each direction was cut and brought back to the laboratory, and the number of each taxa found in each 30cm × 30cm area on the surface of each direction were counted and recorded. For pathogens, the number of total insect and insects infected by pathogen on each branch with 40-cm length were recorded, respectively (Zhang *et al*., 2010; Zhao *et al*., 2013; Liu *et al*., 2015).

***Statistical analysis*:** The shifts in diversity due to the reduction in pesticides were assessed with the following indices (Simpson, 1949; Pielou, 1972, 1975; Hurlbert, 1978): Berger-Parker index (dominant index): $I = A_{max}/N$, where A_{max} means dominant species or individuals of dominant species; Simpson index: $C=\Sigma P_i^2=\Sigma(N_i/N)^2$, where N_i means individuals of 'i' species and 'N' was the whole individuals of all species; Shannon-Wiener index : $H'=-\Sigma P_i L_n P_i$; Margoles index : $D=(S-1)/ L_n S$, where S was numbers of species ; Pylon index : $E= H'/H'_{max} = H'/ L_n S$; Jacquard index : q= $q=c/(a+b-c)$, where 'a' was the number of the species found in the community A, 'b' was the number of species occurred in the community B, and 'c' the number of the common species occurred in the community A and B.

The similarity among arthropod communities in wolfberry orchards of different management regimes was analyzed with principal component analysis (PCA) and cluster analysis (CA) based on Euclidean distance. And the linkage between pests and natural enemies' sub-communities was tested with Canonical Correlation Analysis (CCA). Given the complex of community composition, species have similar biological characteristics and habits were assigned in a functional group or guilds before analysis. Species from the same family or from different families but with similar biological characters and habits were classified into the same guilds.

The differences in arthropod abundance and diversity indices among three management regimes in each sampling dates were analyzed with One-way ANOVA (Statistics Analysis System 9.2, SAS Institute Inc.). Generalized linear model (GLM) was used to assess the overall response of arthropod abundance and diversity indices for management regimes. The statistical significance level was set at $P < 0.05$. Principal component, canonical correlation and cluster analysis were performed in CANOCO 4.5.

RESULTS

***The community characteristics of arthropods in wolfberry orchards of different management regimes*:** Overall, the species richness and abundance of arthropod have significant differences among the organic and conventional orchard, and pesticide free orchard. Overall, total 45 species of natural enemies were identified in wolfberry orchards (Table 1). The species richness of arthropod natural enemies in pesticide free orchard, the organic orchard and the conventional orchard with chemical control was 70.34, 18.78 and 10.87%, respectively (Table 1). Additionally, the differences in dominant index (Berger-Parker index) of the arthropod communities were not significant among wolfberry orchards of different management regimes. The dominant index of arthropod complex in the pesticide free orchard and the organic orchards was higher than that of conventional orchards with chemical control. A sharp shift in dominant index was found for orchard without pesticide application. Particularly, the dominant indexes in the pesticide free orchard inclined from May 15th and decline sharply after July 10th. However, the dominant index in the organic orchard and the conventional orchard with chemical control were relatively stable during the experimental period. Simultaneously, the complex interactions across arthropods in pesticide free orchard accounted for the relatively stable diversity index and no perceptible fluctuation across sampling dates. In contrast, the arthropod community in organic orchard was characterized by lower species richness, oversimplified linkage and obvious seasonal dynamics. Overall, the abundance and species richness of arthropod in the pesticide free orchard was the highest, followed by that the organic orchards and that of conventional orchards with chemical control ranked the least.

***Analysis of cluster and communities characteristic index in different management regimes of Chinese wolfberry orchards*:** The community characteristics of arthropod in wolfberry orchards were depicted in Figure 1. Overall, the abundance, species richness and Berger-Parker index of arthropod in wolfberry pesticide free orchard was higher than other orchards with pesticide application. While the evenness and diversity indices of arthropod community in organic wolfberry orchards were higher than other orchards. The abundance, taxa richness, diversity indices were low in the conventional orchards with chemical control, while the corresponding Berger-Parker index was higher than other orchards. Meanwhile, results from cluster analysis showed that the community structure of arthropod in organic orchards and in conventional orchards with chemical control were comparable, with a distance of merely 0.0314. However, the community structure of arthropods in pesticide free orchard was significantly different from organic orchard.

***Guilds of arthropod in wolfberry orchards of different management regimes*:** From the perspective of taxa richness and abundance, the drilling-leaf pests and pests with piercing-sucking mouthpart were recorded the highest in numbers, followed by the guilds consisted of leaf-feeding, flower-feeding and fruit-feeding insects, and borers-fruit guild was the least (Table 1). *Aceria pallida* Keifer, *Aphis* sp., *Paratrioza sinica* Yang et Li were the dominant species. Carnivorous arthropods were dominated by *Hippodemia variegata* Goeze, *Chrysoperla sinica* Tjeder, *Metasyrpphus nitens* Zetterstedt. The main parasitic enemies were *Tamarixa lyciumi* Yang, and members from Aphelinidae and Eulophidae families. *Misumenops tricuspidatus* Fabricius was the dominant species in the omnivorous guild. Smynthuridae and ixodidae was the dominant underground soil fauna. Finally, all of the wolfberry orchards were featured by the entomopathogenic fungi.

Table 1. Arthropod assemblages in wolfberry orchards for different management regimes recorded from April 3rd to August 21st of 2012 season in Ningxia province of northwestern China.

Order	Species	Pesticide free orchard		Organic orchard		Conventional orchard	
		Abundance	Frequency	Abundance	Frequency	Abundance	Frequency
Hymenoptera	*Ophion luteus*	91	0.67	32	0.24	11	0.08
Hymenoptera	*Goryphus basilaris*	17	1.00				
Hymenoptera	*Eriborus sinicus*	23	1.00				
Hymenoptera	*Coccygomimus disparis*	26	1.00				
Hymenoptera	*Lemophaga japonica*	17	0.68	8	0.32		
Hemiptera	*Nabis sinoferus*	41	0.31	95	0.69		
Hemiptera	*Nabis stenoferus*	23	1.00				
Hemiptera	*Nahia sinoferus*	156	1.00				
Diptera	*Metasyrphus corolla*	435	0.57	231	0.31	89	0.13
Diptera	*Sphaerophoria cylindrical*	56	1.00				
Diptera	*Scaera pyrastri*	24	1.00				
Diptera	*Metasyrphus corollae*	45	0.75	15	0.25		
Diptera	*Scaera selenitica*	12	0.50	12	0.50		
Diptera	*Episyrphus balteatus*	35	1.00				
Diptera	*Didea fasciata*	26	1.00				
Omnivores	*Cicindela chinensis*	14	0.36	13	0.33	12	0.31
Omnivores	*Cicindela hybrida*	12	0.39	10	0.32	9	0.29
Omnivores	*Cicindela elisae*	203	0.48	156	0.37	65	0.15
Coleoptera	*Chalenius pallipes*	198	0.44	156	0.35	96	0.21
Coleoptera	*Calosama Chinense*	65	0.37	58	0.33	53	0.30
Coleoptera	*Nebria livida*	86	0.43	74	0.37	41	0.20
Coleoptera	*Carabus ignimetalla*	9	0.60	5	0.33	1	0.07
Coleoptera	*Propylaea japonia*	856	0.94	56	0.06		
Coleoptera	*Coccinella septempunctata*	681	0.88	96	0.12		
Coleoptera	*Oenopia conglobata*	165	1.00				
Coleoptera	*Adalia bipunctata*	135	1.00				
Coleoptera	*Coccinella trantransversoguttata*	186	0.95	9	0.046		
Coleoptera	*Coccinella quatuordecimpustulata*	65	1.00				
Coleoptera	*Hippodamia variegaga*	865	0.81	103	0.10	103	0.10
Coleoptera	*Hippodamia tredecimpunctata*	49	1.00		0.00		
Coleoptera	*Coccinella undecimpunctata*	58	0.70	25	0.30		
Coleoptera	*Hyperaspis leechi*	9	1.00				
Coleoptera	*Harmonia axyridis*	596	0.81	86	0.12	53	0.07
Coleoptera	*Harmonia dimidiata*	5	1.00				
Coleoptera	*Hydrous acuminatus*	45	0.27	56	0.34	65	0.39
Coleoptera	*Hydrophilus affinis*	26	0.18	65	0.45	54	0.37
Neuroptera	*Chrysopa intima*	396	0.59	169	0.25	103	0.15
Neuroptera	*Chrysopa septempunctata*	195	0.67	95	0.33		
Neuroptera	*Chrysopa formosa*	98	1.00				
Neuroptera	*Chrysopa phyllochroma*	56	1.00				
Coleoptera	*Staphylinus maxllonus*	135	0.61	56	0.25	32	0.14
Coleoptera	*Stenus tenuipes*	35	0.56	16	0.25	12	0.19
Hymenoptera	*Aphidius sp.*	563	0.53	365	0.35	125	0.12
Hymenoptera	*Pauesia jezoensis*	485	1.00				
Hymenoptera	*Iphiaulax impostor*	49	1.00				

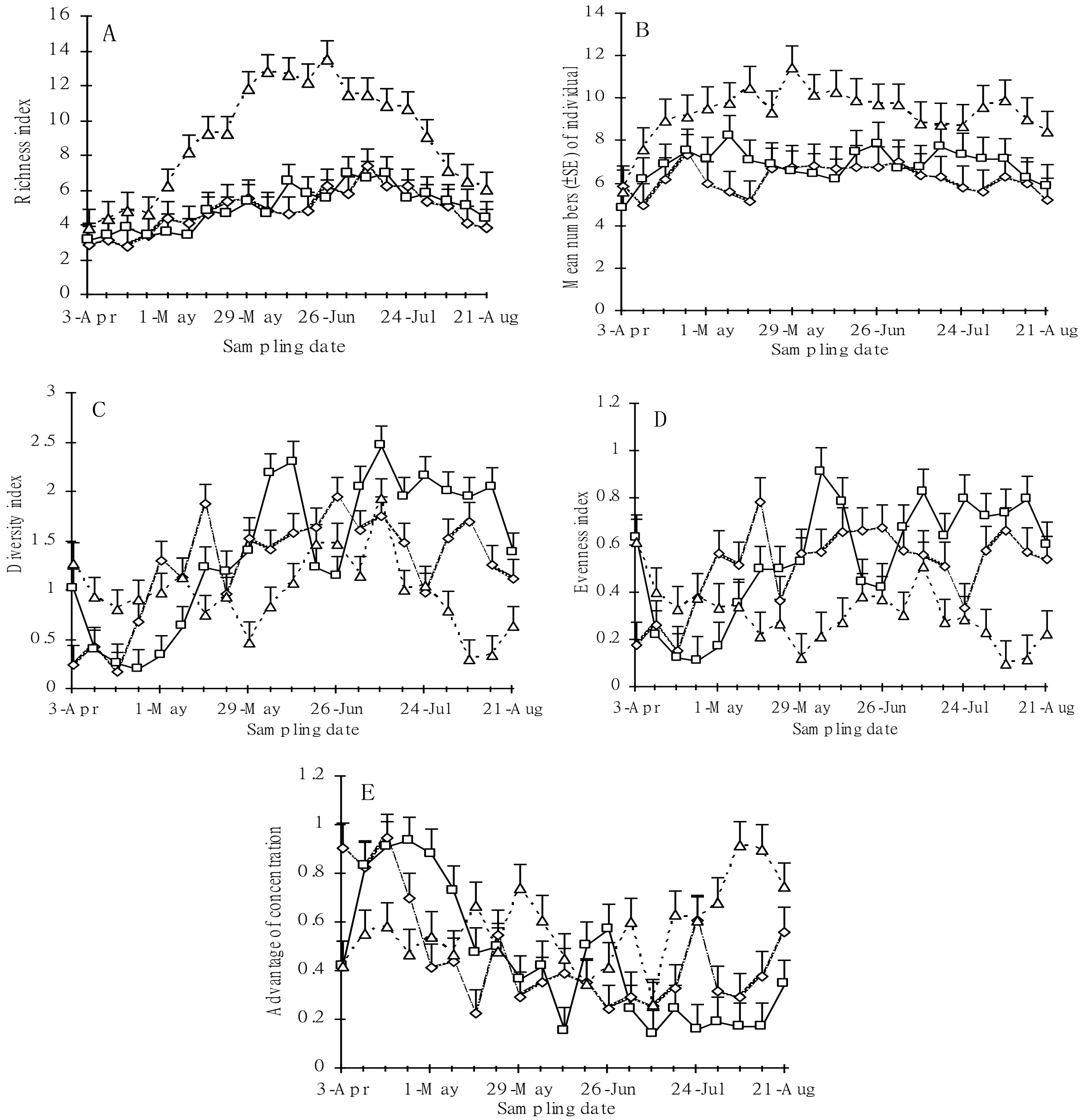

Figure 1. **The differences in arthropod assemblages in wolfberry orchards of different management regimes observed from April 3rd to August 21st of 2012 in Ningxia province of northwestern China.** (A) abundance of arthropod community by Richness Index, (B) mean number (±SE) of species richness, (C) Shannon-weaver index, (D) Evenness index, and (E) Simpson index. The sampling date (X-axis) is shown with 28 days intervals starting from April 3rd to August 21st. Three different management regimes were represented by different graph lines as: '∆' represents the pesticide free orchard (abandoned field), '□' represents the organic field with biological control, and '◊' represent the conventional field with chemical control.

Underlying relationship between natural enemies and pests: The corresponding correlation coefficients for pesticide free, organic and conventional orchards with chemical control were 0.864, 0.683 and 0.733, respectively (Table 2). The parasitic wasp played a very important role in suppressing pests with piercing-sucking mouthpart from early April through August in orchard free of pesticide (Fig. 2A). However, in pesticide free orchard application, the control effects of parasitic wasp to pests with piercing-sucking mouthpart ranged from subtle to zero (Fig. 2B, C).

Table 2. The linkages between natural enemies and pests in wolfberry orchards of different pest control strategies recorded from April 3rd to August 21st of 2012 season in Ningxia province of northwestern China.

Pest control strategy	Linear combination of standardized translation
Pesticide free orchard	X = 0.046x1 − 0.252x2 + 0.596x3 + 0.5210x4
	Y = 0.902y1 + 0.035y2 + 0.022y3 + 0.184y4 − 0.059y5
Organic orchard (with biological control)	X = − 0.185x1 + 0.574x2 − 0.053x3 + 0.449x4
	Y = 1.044y1 − 0.012y2 + 0.077y3 − 0.1348y4 + 0.1928y5
Conventional orchard (with chemical control)	X = − 0.183x1 + 0.977x2
	Y = 0.486y1 + 0.259y2 − 0.153y3 − 0.083y4 + 0.273y5

Note: X-natural enemy, x1- omnivorous, x2- predator, x3- parasitic natural enemies, x4- pathogen natural enemies, Y-pest, y1- pests with piercing-sucking mouthpart, y2- leaf-feeding pests, y3- drilling-leaf pests, y4- borers-fruit pests, y5-flower-feeding and fruit-feeding pests.

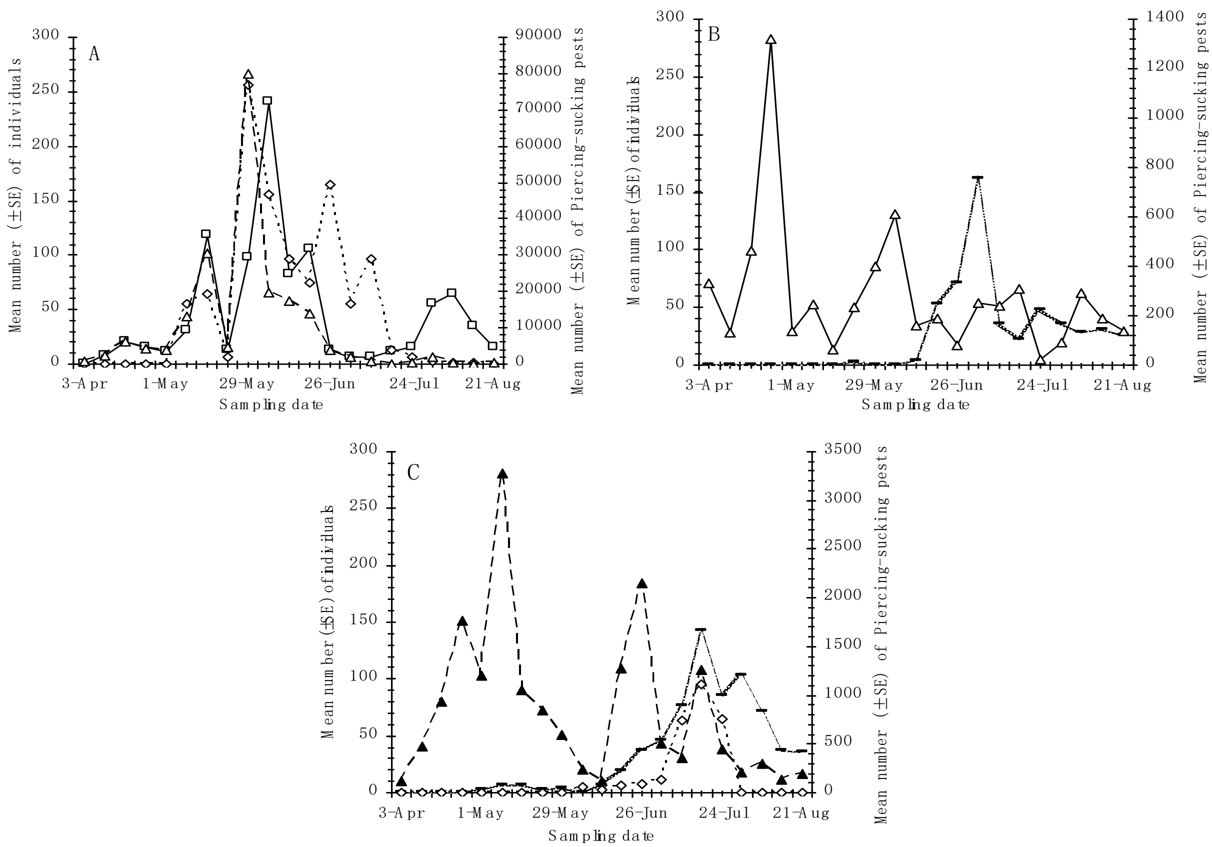

Figure 2. The population dynamics of pests with piercing-sucking mouthparts (Right Y-axis) and major natural enemies (Left Y-axis) in wolfberry orchards of different management regimes. (A) pesticide free orchards, (B) Organic orchard with biological control and (C) Conventional orchards with chemical control. The sampling date (X-axis) is shown with 28 days internal starting from April 3rd to August 21st of 2012. Three different groups of arthropods were represented by different graph lines as: 'Δ' represents the piercing sucking pests, '□' represents the parasitic natural enemies and '◊' represent the pathogen natural enemies.

Comprehensive analysis indicated that the pest was regulated by the synergistic interaction across natural enemy complex, rather than single taxa.

***Shifts in seasonal dynamics of natural enemies' sub-communities and pests sub-communities among wolfberry orchards of different management regimes*:** The population dynamics of arthropod showed contrasting response to management tactics. In the wolfberry pesticide free orchard, the population changes of parasites and pests with piercing-sucking mouthparts were almost synchronous except for a time delay. The abundance of natural enemies was low in early stage, but increased sharply from July 3rd. The population density of natural enemies in conventional orchards with chemical control peaked on June 27th, while it was not sufficient to control pests which out broken in July 30th due to lower abundance and simple community structure. The highest population density of predators was recorded in the organic orchards in July 15th with ample amount of host prey.

***Linkage between arthropod assemblages and environmental factors for wolfberry orchards of different management regimes*:** Vegetation diversity and coverage are major factors limiting the abundance of the drilling-leaf pests, for which the corresponding contribution coefficients were -14.3265 and -9.3652, respectively. Irrigation times had a positive effect on the population size of drilling-leaf pests. The effects of the factors, between pesticide spraying times, richness and abundance of natural enemies were precise. The frequency of pesticides spraying had a strong inhibitory effect on the abundance of leaf eating pests for which the contribution coefficient was -6.9696. The vegetation coverage can greatly inhibit the population size of fruit boring pests, the contribution coefficient was -15.3903. Overall, the abundance of insect pests was regulated by vegetation diversity, vegetation coverage, irrigation times and pesticides spraying times, the corresponding contribution coefficients were -11.3009, -8.3649, 3.3008 and 2.0079, respectively (Table 3).

The vegetation diversity, spraying times, irrigation and vegetation coverage were the positive factors for natural enemy complex. However, pesticide application seriously inhibited the community reestablishment of natural enemy, its contribution coefficient was -26.9652 (Table 4).

DISCUSSION

In the present study, the arthropod assemblages in orchards of different management regimes were compared and the relationships between pests and natural enemies, as well as changes due to management practice were explored. Our results showed that vegetation diversity and plant coverage exerted detectable effects on arthropod assemblages. The vegetation diversity may affect communities living within or near the orchard through an increase in the resource range, i.e. habitat, shelter and food. On one hand, vegetation diversity is negatively correlated to species abundance and richness of pests. On the other hand, high vegetation diversity is favorable to natural enemies community reestablishment, which in turn may enhance the pest suppression. Overall, the direct and indirect effects of vegetation diversity accounted for the arthropod assemblage of lower abundance and high evenness in pesticide free orchard. Theoretically, the plant cover shelters an abundant arthropod community which could not only serve as alternate preys or hosts, but also as pests. Furthermore, the migration of pests towards the cultivated trees is often more affected by the management of the plant cover than by the plant cover itself, and weeding would lead the hosted pests to migrate towards another resource. Accordingly, natural enemies sheltered by the plant cover of the alleys could also be negatively affected by frequent management practices.

A wide range of plant assemblages targeting various pests has already been tested with promising results, adverse effects due to the management of the plant cover on pest control

Table 3. The linkage between the abundance of pests and environmental factors in wolfberry orchards recorded from April 3rd to August 21st of 2012season in Ningnxia province of northwestern China.

Pest feeding type	Regression equation
Drilling-leaf pests	$Y = -14.326x_1 - 9.365x_2 - 6.357x_3 - 2.366x_4 - 1.326x_5 + 9.365x_6 - 3.326x_7 + 6.365x_8$
Pests with piercing-sucking mouthpart	$Y = -13.365x_1 - 6.326x_2 - 3.326x_3 - 0.365x_4 - 0.369x_5 + 4.326x_6 + 1.326x_7 + 5.6539x_8$
Fruit pests	$Y = -15.390x_1 - 8.238x_2 - 1.369x_3 - 0.969x_4 + 1.9693x_5 + 3.358x_6 + 1.000x_7 + 7.996x_8$
Defoliator	$Y = -10.399x_1 - 9.636x_2 - 6.969x_3 - 0.366x_4 - 1.212x_5 + 2.303x_6 + 0.393x_7 + 6.396x_8$
Flower-feeding and fruit pests	$Y = -9.395x_1 - 12.236x_2 - 3.003x_3 - 2.003x_4 + 1.263x_5 - 1.399x_6 + 0.360x_7 + 5.909x_8$
Pest complex	$Y = -11.300x_1 - 8.364x_2 - 2.007x_3 - 0.393x_4 - 2.260x_5 + 5.006x_6 + 9.003x_7 + 3.300x_8$

Note: x1- plant diversity, x2- plant coverage, x3-times of pesticides application, x4-richness of natural enemies, x5-abundance of natural enemies, x6-richness of arthropod, x7-abundance of arthropod, x8-times of irrigation.

Table 4. The linkage between the abundance of natural enemies and environmental factors in wolfberry orchards recorded from April 3rd to August 21st of 2012 season in Ningnxia province of northwestern China.

The feeding type of natural enemies	Regression equation
Predator	$Y = 33.618x_1 - 4.488x_2 - 17.812x_3 + 3.081x_4 - 0.008x_5 + 2.417x_6 - 0.002x_7 - 6.961x_8$
Parasitism natural enemy	$Y = 23.659x_1 + 1.236x_2 - 39.265x_3 - 6.365x_4 - 0.006x_5 + 3.698x_6 + 4.362x_7 - 5.698x_8$
Pathogenic natural enemy	$Y = -5.395x_1 + 17.236x_2 - 3.362x_3 - 2.365x_4 + 1.263x_5 - 1.399x_6 + 1.369x_7 + 21.961x_8$
Omnivorous	$Y = 23.365x_1 + 15.365x_2 - 9.365x_3 - 3.265x_4 - 5.326x_5 + 6.325x_6 + 2.326x_7 + 3.325x_8$
Natural enemy complex	$Y = 15.399x_1 + 3.695x_2 - 26.965x_3 - 2.369x_4 - 1.269x_5 + 5.362x_6 + 9.368x_7 + 6.396x_8$

Note: x1-plant diversity, x2-plant coverage, x3-times of insecticides application, x4-richness of pests, x5-abundance of pests, x6-richness of arthropod, x7-abundance of arthropod, x8-times of irrigation.

occasionally occurred as well (Massey and Young, 1975). Although the plant ground cover can be easily manipulated and experimented on, its role in failure or success of pest control cannot are not fully understood since the results are not always reproducible to date. Similarly, the linkages between plant characteristics and arthropod assemblages are not clear in this study. Further research is needed to identify occurring processes and the ability of both pests and beneficial arthropod species to exploit both understory and plant resources change due to the discrepancy in management. Our findings demonstrated a striking difference in the structure of arthropod community among the wolfberry orchards with different pesticide applications. This finding was consistent with early study suggesting the structure of the arthropod community differed among high - and low - intensity pest management regimes (Andreev *et al.,* 2006). For instance, the drilling-leaf pests and pests with piercing-sucking mouthpart, which are the main targets by arthropod natural enemies and also the principal impediment for the green or organic wolfberry, were the most important groups in wolfberry orchards of different management regimes. On one hand, the flower-feeding and fruit-feeding pests had the potential to become dominant species due to decreased interspecific competition under the selection pressure of specific pesticides. On the other hand, the flower-feeding pests and fruit-feeding pests mainly fed on the flowers and fruits of wolfberry, and they may transmit *Colletotrichum gloeospor ioides* Penz and lead to the reduction in the quantity and quality of wolfberry fruits. The population densities of the flower-feeding pests in the organic orchard with biological control and in the conventional orchard with chemical control were higher than those in orchard free of pesticide. This finding suggested that the community structure of arthropods was clearly related to pesticides application. Meanwhile, it is worthwhile to note that arthropod assemblage would shift with the application of pesticides. Numerous studies have documented that restricted use of pesticides may enhance biological control, a valuable ecosystem service (Bianchi *et al*., 2006; Losey and Vaughan, 2006; Lu *et al*., 2012), and thus could favor the development of sustainable farming (Landis *et al*., 2000; Crowder *et al*., 2010). In our study, the omnivorous are common in wolfberry orchards of different management regimes. However, they cannot control pest effectively due to low abundance. For example, the omnivorous natural enemies, the dominant taxa in the organic orchard with biological control and in the conventional orchard with chemical control, were not able to suppress the outbreak of pests. Their top-down effects on the pests may be disrupted by the frequent pesticides application and farming operations. In the pesticide free orchard, the parasitoids were the dominant group and they can efficiently suppress the pests. This finding highlighted the importance of conservation biological control in a given agro-ecosystems. Integrated control strategies of wolfberry pests should be designed by attracting naturally-occurred parasitoids (e.g. planting flowering plants), by the release of commercially-reared parasitical wasps, or a combination of both.

Our data clearly demonstrated that plant diversity and pesticides application frequency in orchards could exert considerable impact on natural enemy complex. These findings shed light on how to enhance the yield of wolfberry while posing minimal negative impact on the environment. This may be achieved by reducing the insecticide application while protecting the plant diversity in the habitat. Studies on arthropod community composition and its spatiotemporal dynamic can provide theoretical basis for the conservation of natural enemy and the enhancement of biological control in wolfberry orchards. Future studies should focus on the roles of key pests as well as their key arthropod natural enemies in wolfberry production.

Conclusion: The different modules of pests varied in their responses to environmental factors depending on different feeding types. The linkage between arthropod community and environmental factors indicated that vegetation diversity, plant coverage, pesticide application and irrigation times exerted detectable contrasting effects on arthropod community and population dynamics. Finally, we suggest that habitat management (i.e. increase in plant cover and diversity) may serve as effective tactics for preventing pest population from reaching the economic injury level which minimizing the input of pesticides and fertilizers.

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