JOURNAL OF THE NACAA

ISSN 2158-9429

VOLUME 4, ISSUE 1 - JUNE, 2011

Editor: Donald A. Llewellyn

NET HOUSE VEGETABLE PRODUCTION: PEST MANAGEMENT SUCCESSES AND CHALLENGES

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ABSTRACT

Vegetable producers are consistently challenged by insect pest outbreaks. Physical barriers, e.g., row covers, are commonly used by producers for excluding insects from host plants. However, exclusion efficiency of a large net house for vegetable production has not been scientifically evaluated before in the United States. To fill this gap in information, a net house was constructed in Alabama for producing tomatoes and bell peppers. This net house was 150 feet (L), 48 feet (W), and 17 feet (H) constructed entirely of 50-mesh insect netting. Only double-doors provided access inside the net house for transplanting crops and routine maintenance. Insect pest activity was monitored in the net house as well as outside (untreated check plots) using pheromone traps. Plants were scouted directly to determine pest pressures. The net house significantly excluded moths of tomato fruitworm (*Helicoverpa zea*) and beet armyworm (*Spodoptera exigua*) compared to the open field; exclusion efficiency was 82-100%. Direct scouting revealed armyworms (three species) and the tomato hornworm (*Manduca quinquemaculata*) caterpillar numbers reduced 98-100% under the net house. Leaffooted bugs (*Leptoglossus* sp.) were also undetectable on plants grown inside whereas open-field tomatoes were severely damaged by the insect. The net house also reduced number of pesticide applications by 90%. Major challenges of the net house crop production system included high humidity and temperature inside the unit which facilitated disease and aphid outbreak. Further studies are needed to resolve those issues and develop the net house technology for season extension. Implications of these finding for organic vegetable production are discussed.

INTRODUCTION:

Alabama is a significant producer of vegetables in the United States (U.S.) with over 40 different types grown under various agroclimatic conditions. Tomatoes and bell peppers are some of the major vegetables produced by the state because of high consumer demand for fresh produce and good returns. However, high insect pest pressures are a barrier to the proliferation of the vegetable industry, including the organic market (Majumdar, 2010). Although a few alternative insecticides are available for the organic producers, effectiveness of insect exclusion using a net house has received limited or no attention in the United States (U.S.) resulting in information gaps. In many parts of the world, nets or screens are commonly used in crop production for reducing excessive solar radiation, weather effects on produce, or to keep away insects. Net houses can be of variable height and width; some large net houses spread over hundreds of acres have been constructed in South America (http://www.amfarmsyst.com/). Net houses or its variants also have been successfully used in some European and Southeast Asian countries for producing cabbage (Martin et al., 2006) and egg plants (Kaur et al., 2004). In Africa, movable net houses made of mosquito nets (25-mesh) were effective as a physical barrier against the diamondback moth, cutworms, and loopers providing 66 to 97% control of moths and caterpillars (Martin et al., 2006). Insect nets have also been tested in conjunction with hoop houses in the Germany with a great success (e.g., Mutwiwa and Tantau, 2008).In China, Feng-cheng et al. (2010) demonstrated 90% reduction in the occurrence of tomato yellow leaf curl virus due to the near elimination of whiteflies using a 50-mesh net house. In the U.S., large arched net houses have been constructed in California and Florida on 70+ acres for bell pepper, tomato, chili, and citrus production; however, very little scientific evaluation of the technology has been completed and farmers have depended on vendor's recommendations for adopting the technology (e.g., Top Greenhouses Limited of Israel is a major marketer of net houses in the U.S.; visit www.top.pro for more information). Based on these past reports, the main goals of this preliminary net house study were to: 1.) build the first net house dedicated to vegetable production in Alabama; 2.) compare the insect exclusion efficiency (level of reduction of insect pests) of the net house. This is the first scientific study of a net house built exclusively for vegetable production in Alabama; trends reported herein need to be corroborated with further research.

METHODOLOGY:

Construction of the Net House

Net house is sealed structure made of insect net (polyester fabric) designed to keep insects away from plants by physical exclusion. For this study, a large net house (150 feet by 48 feet) was constructed in Baldwin County, Alabama – an area of historically high insect pest pressures (Majumdar, 2010). Construction of the net house began in April (2010) and was completed in May (2010). The net house was constructed in the east-west direction. The site selected for installation of the unit was a level field on a commercial vegetable farm with sandy loam soil. The 50-mesh insect netting used in this study was provided by the American Farm Systems (Jemison, AL) – a subsidiary of PolyProductos De Guatemala S.A., Guatemala. A 50-mesh fabric can exclude large and small insects and the fabric lasts up to 5 years under normal conditions. Long pieces of the fabric were stretched over wooden poles which were 17 feet tall in the center and 14 feet at the sides giving the net house a sloped roof. A network of cables ran between the wooden poles; the cables eventually anchored to the ground providing stability to the structure. The fabric was slowly pulled across the length of the unit to prevent air trap during construction. The height and width of this net house allowed full use of a tractor for laying down the plastic, drip tape and fumigant in one operation before the east and west walls were closed. Before transplanting tomatoes and bell peppers, all the fabric side-walls were buried 2-3 feet underground to make the walls firm and seal the structure. Drip tape was installed to provide irrigation to the vegetable crops. A pair of double-doors on the east side of the net house allowed access inside the unit; when not in use, those double doors were kept closed to limit accidental introduction of insects. Three rows each of ‘California Wonder’ bell peppers and ‘Celebrity’ tomatoes were transplanted manually after the structure was sealed. Three long patches of tomatoes and bell peppers in the vicinity of the net house served as the check plots for this study.

Determining Insect Exclusion Efficiency of the Net House

Insect exclusion efficiency is the percentage reduction in pest activity inside the net house compared to the normal conditions. The activity of moths was determined by comparing trap catches in sticky wing pheromone traps installed inside and outside the net house (along the untreated check plots). Pheromone traps included a species-specific lure placed on a replaceable sticky bottom. Pests monitored included the tomato fruitworm, tobacco budworm, loopers (two species), fall armyworm, and beet armyworm (Table 1). Moth trap catches, recorded every 10 days, indicated the population density and mating for particular pest species. In order to fully determine pest pressures, bell peppers inside and outside the net house (untreated check) were scouted to determine the number of caterpillars on 40 randomly chosen plants.

RESULTS & DISCUSSION:

For readers wanting to know more about this net house research and photos of the structure, please visit http://www.aces.edu/timelyinfo/entomology/2010/December/Dec_2010.pdf.

Insect Exclusion efficiency of a Net House

The net house was very effective in reducing moth and caterpillar numbers on vegetables grown under the large structure. Information based on pheromone trap catches (Table 1) indicated 82-100% reduction in the activity of moths inside the net house compared to the open field. Beet armyworm and loopers were first recorded in June of 2010. Interestingly, there was one outbreak of aphids under the net house which is consistent with observations from other studies (e.g., Talekar et al., 2003). Cotton aphid (*Aphis gossypii*) and potato aphid (*Macrosiphum euphorbiae*) were the predominant species detected in this study. Based on crop scouting, there was also a significant reduction in the number of caterpillars observed on 40 random plants located inside and outside the net house. Armyworm caterpillars were detected in low numbers inside the net house but heavy populations occurred outside (Table 2). Armyworm moths were seen laying eggs on the insect netting and the newly hatched caterpillars crawled across the fabric through the minute openings along the seams (Majumdar, personal observation); interestingly, Talekar et al. (2003) had similar experiences with the net house vegetable production system in Taiwan. It is suspected that aphids were introduced into the net house via infested transplants at the beginning of the season (delayed planting in 2010 may have also aggravated the aphid populations). Thus, farmers adopting the net house production system have to be vigilant and scout their crops regularly to detect accidental invasions. Exclusion of natural enemies also aggravates pest problems in the net house. In this study, aphids on bell peppers were managed with a single application of pymetrozine (a feeding inhibitor manufactured by Syngenta Crop Protection, Greensboro, NC) at the full recommended rate; there was no resurgence of aphid populations through the rest of the season.

Besides aphids, some grasshopper got trapped during the construction process. Those the grasshopper populations naturally decreased as the season progressed and no insecticidal intervention was necessary. Only one brown stink bug (*Euschistus servus*) adult but zero leaffooted bugs were found inside the net house suggesting high exclusion efficiency of the net house. Leaffooted bugs (*Leptoglossus* sp.) were as high as 2 to 4 per untreated tomato fruit grown outside the net house. Eggplants growing adjacent to tomatoes had over 6 leaffooted bugs per fruit which caused heavy fruit drop in the field. In short, vegetable producers should first determine the target insect in order to determine the required mesh size for their net house. Choosing a lighter fabric (25, 30 or 40 mesh) and smaller design could cut the net house construction cost drastically without sacrificing insect exclusion efficiency.

Table 1. Reduction in moth numbers inside the net house recorded using sticky wing pheromone traps, Baldwin County, Alabama (2010)

	Tomato fruitworm (*Helicoverpa zea*)		Tobacco budworm (*Heliothis virescens*)		Loopers[b]		Beet armyworm (*Spodoptera exigua*)		Fall armyworm (*S. frugiperda*)	
	Net house[a]	Open field	Net house	Open field	Net house	Open field	Net house	Open field	Net house	Open field
May	0	1	0	2	0	0	0	8	0	13
June	0	1	0	2	0	17	0	23	0	15
July	0	2	1	23	0	27	0	40	2	11
August	0	7	0	10	0	23	0	69	4	11
Sept.	0	8	0	5	0	37	0	75	5	14
Mean (± SD)	0	3.8 (± 3.4)	0.2 (± 0.4)	8.4 (± 8.8)	0	20.8 (± 13.7)	0	43 (± 28.9)	2.2 (± 2.3)	12.8 (± 1.8)
Insect exclusion efficiency (%)[c]	**100%**		**98%**		**100%**		**100%**		**82%**	
ANOVA[d]	*F*= 6.171, *P*= 0.038*		*F*= 4.338, *P*= 0.071		*F*= 11.494, *P*= 0.009**		*F*= 11.092, *P*= 0.01*		*F*= 66.681, *P*= 0.0001***	

[a]Insect trap catches are cumulative for two observations each month. Trap catches indicate population density and activity of moths.

[b]Includes soybean and cabbage loopers.

[c]Insect exclusion efficiency is the percentage reduction in pest numbers inside the net house compared to normal conditions.

[d]Analysis of variance using SPSS Version 13.0.

Table 2. Reduction in caterpillar numbers inside the net house compared to open-field vegetable production, Baldwin County, Alabama (2010)

	Armyworms[a]		Hornworm[b]	
	Net house	Untreated control (open field)	Net house	Untreated control (open field)
Total caterpillar nos. (40 random plants)	7	32	0	17
Mean (± SD)	0.1 (± 0.3)	0.8 (± 0.8)	0	0.4 (± 0.6)
Insect exclusion efficiency (%)[c]	**78%**		**100%**	
ANOVA[c]	*F*= 16.845, *P* = 0.0001**		*F* = 15.852, *P* = 0.0001**	

[a]Includes the total number of beet (*Spodoptera exigua*), southern (*S. eridania*) and fall armyworms (*S. frugiperda*).
[b]*Manduca quinquemaculata*

[c]Insect exclusion efficiency is the percentage reduction in pest activity inside the net house compared to the normal conditions outside the unit.

[d]Analysis of variance using SPSS Version 13.0.

Net House Crop Production Challenges

Plant growth: Although plant establishment and crop growth were very encouraging in this study, the net house technology offered several challenges, for example:

1.) High heat and humidity levels: The lack of adequate ventilation under the 50-mesh net house raised the internal temperatures to 138°F in July and August (Table 3) which was stressful to the plants. The prolonged drought in Alabama in 2010 also contributed to the high heat levels. Producers may install large fans or use a lighter netting to improve air circulation.

2.) Unsuitable varieties & disease pressures: It appears that the vegetable varieties used in this study were not suitable for delayed planting under the net house (there was no prior publication on net house vegetable production system for our reference). Humidity levels reached ~99% on some days which favored disease development (e.g., root rot in tomatoes) and fruit deformities in bell peppers. A retractable 40-percent black shade cloth was later installed under the insect netting which reduced the heat levels and promoted better plant growth.

Crop harvest: Due to significant disease pressure in this first year study, plant yields were not consistent. Therefore, yield data has been excluded from this report until trends are confirmed with additional studies in future.

Table 3. Microclimate under the net house used for vegetable production compared to the weather conditions outside, Baldwin County, AL. The year 2010 was a drought year.

	MICROCLIMATE UNDER NET HOUSE		CLIMATE OUTSIDE (AWIS*)		
	Range of Temp. (F)	Range of Relative Humidity (%)	Average Temp. (F)	Average Relative Humidity (%)	Rainfall (inches)
Early May	NA	NA	77	93	2.04
Late May	69-125	28-99	84	100	5.13
Early June	68-122	26-99	82	94	2.4
Late June	75-114	35-99	84	98	1.9
Early July	76-102	59-98	84	98	0.5
Late July	76-113	42-99	113	100	1.37
Early August	77-138	39-99	85	98	2.31
Late August	75-139	38-95	88	100	6.28
Early September	NA	NA	81	96	3.43
Late September	NA	NA	78	95	3.95

*Alabama Weather Information System

FUTURE DIRECTIONS IN THE NET HOUSE RESEARCH

It is clear from the preceding discussion that the net house vegetable production system is not a ‘silver bullet’ solution to all pest problems. The net house vegetable production provides many insect control advantages as well as disease management challenges which can be resolved with continued research. Occasional insect pest outbreaks observed under the net house crops may have been due to insects emerging from the soil along grassy borders (e.g., grasshoppers), using infested transplants (e.g., aphids), or small caterpillars crawling across the seams (e.g., armyworms). It is probable that pest infestations inside the net house were increased by the exclusion of natural enemies. The impact of inundative release of natural enemies under large net houses for reducing pest outbreaks needs to be evaluated in future studies.

Due to the moderate upfront cost of the net house vegetable production system (about $10,000 for construction materials, insect fabric, and labor for a 7200 sq ft unit), it is anticipated that organic crop producers may be more willing to use the net house vegetable after adjusting the technology to their managerial ability, location, and target insect. Organic vegetable producers can make small net house and use OMRI-approved insecticides for controlling insect outbreaks early in the season, if needed. Cost of the net house can be off-set by the long life of the high quality structure and the higher price of organic produce in the market. Unused hoop house frames covered with insect netting can also serve as a net house for the low-resource farmers. Home vegetable gardeners may be able produce crops under net houses using nets sold locally at the public stores; Alabama Cooperative Extension System has initiated studies in building and evaluating such low-cost net houses across different pest pressure regions of the state. Farmers interested in the net house vegetable production system should contact an expert on integrated pest management and/or protected agriculture at a university for consultation before making large investments.

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