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Overview of the Integrated Pest Management (IPM) Terrain and Activities in Furtherance of the Walmart Initiative to Purchase Fresh Vegetables from Local Growers in Alabama

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OVERVIEW OF THE INTEGRATED PEST MANAGEMENT (IPM) TERRAIN AND ACTIVITIES IN FURTHERANCE OF THE WALMART INITIATIVE TO PURCHASE FRESH VEGETABLES FROM LOCAL GROWERS IN ALABAMA

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Abstract
Tuskegee University has been providing various types of technical expertise to limited resource farmers who have been supplying Walmart with collard greens, watermelons and purple hull peas. A number of pests bedevil the cultivation of these crops; cost-effective management methods for these pests are needed. The objectives of this paper are to document the IPM activities associated with supplying produce to Walmart; summarize pest problems encountered on the afore-stated crops; recommend IPM methods suitable for limited resource farmers; and suggest other activities that ensure that farmers incur even less pest-related crop losses. Anthracnose was the major pest encountered on watermelons. Some purple hull pea growers had problems with purple hull pea curculio and downy mildew. The major pests encountered on collard greens were diamond-back moth and downy mildew. Pesticide residues on vegetables produced and consumed in the U.S. and possible pest management practices that are responsible for these residues are discussed.

Key Words: Pesticide Residues, Pesticide Resistance, Environmental Cost, Polar Vortex, Beneficial Insects

Introduction
Limited resource farmers encounter a myriad of problems in their quest to produce and market wholesome food to consumers at prices that reward them adequately for their efforts. Most Socially disadvantaged farmers in Alabama cultivate vegetables on acreages that are usually small (1-20 acres). Most of these farmers cultivate okra, eggplant, collard greens, cabbage, lettuce, purple hull peas, sweet potatoes, and sweet corn. These farmers encounter both production and marketing constraints. Produce are sold at local farmers markets, sides of busy streets, or at other vantage locations such as gas stations. These produce are sometimes not kept in refrigerated units, a situation which shortens their shelf-life and results in additional pressure on producers to sell or otherwise dispose of their produce quickly to avoid spoilage. Quick disposal is done either by slashing down prices or donating produce to the needy in the community. The Walmart Initiative to "buy local" has resulted in a situation in which participating farmers are guaranteed ready market for their produce by one of the largest retailers in the world.

Large retailers usually have more exacting eligibility requirements for producers compared to their small counterparts and farmers markets. Requirements include good agricultural practices (GAPs)/food safety certification. Appropriate and safe pest management methods/practices are important aspects of GAPs. A major concern is the level of pesticide residues on produce sold to consumers. High pesticide residues on farm produce are attributable to a number of factors such as off-label use of pesticides; off-label use of pesticides covers a wide swathe of infractions including higher than recommended application rates, harvesting crops within the pre-harvest interval (PHI), and the use of pesticides on crops for which they are not registered. It also includes the use of the sublethal dosage of pesticides resulting in increased pesticide resistance in pests which in turn leads to the increased application of pesticides in order to maintain the level of success achieved in previous pesticide applications. The pest management/pesticide aspect of GAPs also focusses on the safe storage of pesticides and proper disposal of pesticide containers. Even though the Walmart Initiative guarantees a ready market for participating farmers, it also comes with the afore-stated and other requirements such as record-keeping. A number of these practices/requirements are either new to the farmers or are required at levels that are higher than those obtained before this initiative.

The objectives of this paper are to document the IPM activities associated with supplying produce to Walmart; summarize pest problems encountered on the afore-mentioned crops; recommend IPM methods suitable for limited resource farmers; and suggest other activities that ensure that farmers incur even less pest-related crop losses.

Overview of Selected Vegetable Crops, their Major Pests, and Management Methods

Surveys of farmers at agricultural field days and farmers conferences at Tuskegee University in 2010 and 2011 revealed that limited resource farmers in the Black Belt Region of Alabama mainly grow vegetables. The results also revealed the percentages of respondents who engaged in the cultivation of specific vegetables: Okra (72%), collard greens (67%), tomatoes (55%), peas (50%), peppers (38%), squash (33%), cabbage (28%), beans (22%), eggplant (17%), sweetpotatoes (17%), and medicinal herbs (17%). The Walmart Initiative currently involves three crops: watermelons, purple hull peas, and collard greens. The retail giant and the College of Agriculture, Environment and Nutrition Sciences (CAENS) have been collaborating over the last 3 years to assist farmers to meet the eligibility requirements to supply Walmart with these crops.

As is typical of most agroecosystems, a number of pests are associated with the cultivation of these crops. The removal of a diverse group of plants (weeds) during plowing and the introduction of a uniform set of plants (crops) reduce the diversity of plants on the farm. Nature generally favors diversity and thus natural forces act in ways to recover or re-introduce a high level of diversity. Pests are examples of such natural forces; they increase in population and cause serious damage to the crops. The affected crops either die or are so weakened as to compromise their competitive ability. This section lists and discusses various pest problems encountered for the specific crops, the underlying causes, recommended management practices, and general pest management recommendations for subsequent seasons. The decision to focus management discussions on specific pests is simply to emphasize major problems encountered in the past and not meant to depict other major pests as economically unimportant.

Watermelons

In the U.S., the leading producers of watermelon in 2012 were Florida and Georgia, followed by California and Texas. These four states accounted for 65% of watermelon production in the U.S. in 2012 (USDA-NASS, 2013). Insect pests of the crop include aphids, whiteflies, cucumber beetles, armyworms, cabbage loopers, the rindworm complex (cabbage looper, beet armyworm, tobacco budworms, corn earworms), pickleworm, melon worm, leaf miners, thrips, seed corn maggot, wireworms, mole crickets (Webb, 2013), and squash bugs. Watermelon diseases include soil borne diseases such as *Phythopthora* crown and fruit rot, *Pythium* cottony leak, *Rhizoctonia* belly rot, and *Fusarium* wilt; this wilt has caused problems in other states including Georgia but was not a major problem for Alabama farmers participating in the Walmart Project. There are also foliar diseases of cucurbits such as Anthracnose, *Alternaria*, gummy stem blight, powdery mildew, and downy mildew. Aphids and anthracnose were the major pest problems encountered in 2013; hence, the decision to focus pest management discussions on these pests.

Aphids

Aphids (family: aphidae) have piercing-sucking mouthparts with which they suck juice from plants and also transmit diseases to infested plants. The first sign of melon aphid damage is a downward curling and crumpling of the leaves. Leaves of infested plants appear thickened and honeydew extruded by the aphids onto these leaves gives them a shiny appearance. Heavy infestations may kill very young plants. Aphids transmit potyviruses such as papaya ringspot virus, watermelon mosaic virus, and Zucchini yellow mosaic virus through feeding activities. According to Elwakil and Mossler (2013), these stylet-borne (i.e., mouthpart-borne) viruses are transmitted in a non-persistent manner. Non-persistence in this case refers to the ability to pick up and immediately transfer virus particles to healthy plants without circulation of the virus in the aphid's body. It must also be noted that the window of time within which the aphid is able to transmit the virus is short. Transmission to watermelon plants can occur within 10 –15 seconds when aphids are probing (inserting their stylets into plant tissues to test their suitability as a source of food). Given the relatively short amount of time required for the transmission of these viruses, control of aphids is not an effective method of controlling these diseases.

Management of aphids begins with monitoring of plants for the symptoms described earlier. The underside of leaves should be the main focus during examination of plants for aphids. Corrective action in the form of pesticide application should be carried out if an average of more than 5 to 10 aphids is found per leaf on 20 to 50 leaves taken throughout the field. Localized infestations may be treated by spot treatment with recommended insecticides (Webb, 2013). Even though reflective mulches may slow down infestations on plants in the early stages of growth, they cease to be effective when they get covered by foliage of mature plants. Lady beetles, lacewings, and larvae of syrphid flies feed on aphids and are therefore beneficial organisms. Some parasitic wasp species lay their eggs in aphids; wasp larvae mature and feed inside the living aphid, leaving behind a tan shell when they exit. Fungi occasionally infect aphids causing drastic reductions in their population. It is important to note that there are currently no aphid-resistant commercial watermelon varieties to combat this problem. It is highly recommended that fields with a recent history of cucurbit virus infection and plants such as cotton which are good sources of aphids, be avoided in site selection (Webb, 2013). Sites of earlier plantings of cucurbits should also be avoided because aphids tend to favor younger plants and so might move to the young watermelon plants.

Anthracnose

The development of this disease, caused by the fungus *Colletotrichum orbiculare*, is greatest during humid, rainy weather. The disease when uncontrolled can destroy an entire field especially after several days of warm, rainy weather which are the conditions that prevailed in most parts of Alabama during the 2013 growing season. It is extremely important to note that this fungus can be carried in the seed and can survive between crops on volunteer plants and infected plant debris. Spores are spread by splashing rain, wind, human beings, and machinery (Robert and Kucharek, 2005). The use of resistant varieties in Florida has limited this disease which in the past caused major damage to watermelons in that state.

Selection of “resistant” watermelon varieties must, however, be carried out carefully because there are three known races of anthracnose (i.e., races 1, 2, and 3) and specific watermelon varieties may be resistant to some races and not to others. Anthracnose 2 (i.e., race 2) has caused serious damage to watermelons in the southeastern U.S. Anthracnose shares early symptoms with gummy stem blight and downy mildew; these symptoms may affect all aerial parts of the plant and include angular, brown to black leaf spots on older leaves. Tan, oval-shaped lesions may appear on the stems. The fruits are later infected by spores from leaf and stem lesions, resulting in spots that are sunken and water-soaked. Severe anthracnose infections sometimes result in death of plants (Elwakil and Mossler, 2013).

Management of this disease involves use of resistant varieties, rotation away from plants in the cucurbit family for at least one year, good sanitation practices such as the immediate destruction of infested debris, use of drip instead of sprinkler irrigation, and the use of recommended fungicides or mixture of fungicides. It is important to contact Extension specialists, county agents and the most current version of the Alabama Pest Management Handbook for the most current information on recommended pesticides that are effective against specific pests on specific crops. This is because pesticides that received rave reviews a few seasons ago may no longer be the most effective products against the pest currently.

Purple Hull Peas

This warm-season crop is a staple crop in the southeastern U.S. The crop may be plagued with pests, especially diseases, when planted in cool soils (Smith and Shaughnessy, 2003). Major insect pests of peas include purple hull pea curculio, aphids, stink bugs, leaf-footed bugs, and lesser cornstalk borers. Although many diseases affect peas, few are very severe; major ones include fusarium wilt (which can damage non-resistant varieties), root-knot nematodes, and southern stem blight. Vertebrate pests such as deer and rabbits can also be major pests that eat young purple hull pea plants and nip tender leaves. The purple hull pea curculio is one of the most devastating pests of purple hull pea.

Purple Hull Pea Curculio

Purple hull pea curculio (*Chalcodermus aeneus*), a weevil, is one of the most devastating pests which attack purple hull peas. The adult is an oval, hump-backed, bronze-tinged, black weevil that has small dents on the wing covers and on the upper side of the body (Griffin, 2014). Damage caused by purple hull pea curculio in purple hull pea is two-fold. The first type of damage occurs when adults feed on and lay eggs in the pods; the eggs hatch into larvae that feed inside the pods causing significant reductions in the yield of green pods and shelled pea per acre. The second part of damage occurs when live larvae inside the harvested pods contaminate and drastically reduce the marketability of peas during processing (Riley et al., 2014). Curculios-damaged pods are characterized by small, brown, wart-like or blister-like spots. These are caused when the adult punctures the pod to feed or lay eggs. Peas damaged by this insect often contain grubs and are characterized by small, dark, indented spots (Griffin, 2014).

The pest overwinters as adults in crop residue, in grass in the field or on the border of the purple hull pea field (Griffin, 2014), where tufts of broom sedge are favorite hiding places. Adults emerge with the return of favorable conditions to begin feeding (Capinera, 2009). One source of infestation is wild host plants which produce pods that attract many curculios (Griffin, 2014).

The insect appears to be bivoltine (i.e., has two generations per year) in Alabama but is univoltine (i.e., has one generation in a year) in Virginia. The pest status of this insect is increased by that fact that adults are capable of surviving for several months. Adult weevils are most active during mornings and early evenings but seek shade during hot periods of the day. This insect plays possum (i.e., feigns death) and drops to the soil when it feels threatened or is disturbed (Capinera, 2009). The adult weevil overwinters in the soil, under leaves, and other organic debris. A species of the fungus *Beauveria*, the parasitoid *Myiophasia globosa* (Townsend) (Diptera: Tachinidae), and certain species of ants including the red imported fire ant, *Solenopsis invicta* Buren (Hymenoptera: Formicidae) are all natural enemies of this insect pest.

The thickness of the pod wall is a major factor in host plant resistance. Thick walls, however, do not offer complete protection under conditions of high pest densities; this necessitates the use of an integrated approach that involves crop rotation, destruction of crop, destruction of alternate hosts (including crop and weed species) as well as tillage practices. Late purple hull peas isolated from early peas are usually not as severely damaged as early peas. Crop rotation and pesticides constitute the major management methods for the pest; preventive spray programs in particular are viewed as the only feasible approach to the control of curculios. The recommended spray schedule begins with a spray at first bloom and repeat treatments made on a five- to seven-day schedule (Griffin, 2014). Insecticide treatments should be targeted at adults and are especially beneficial when directed to the soil beneath purple hull pea plants; this is because adults often aggregate there during the hot periods of the day (Chalfant, 1973). According to Chalfant et al. (1982) treatment of mature pods is not necessarily beneficial. Careful choice of pesticides and rotation of same is very important because insecticide resistance has been responsible for some treatment failures against this pest.

Collard Greens

This is a cool season crop that is grown during early spring or fall (Sanders, 2001) and is one of the most popular garden vegetables in the south. A number of insect pests and diseases attack collards, causing major damage in situations where these pests are not managed properly. Insect pests include diamondback moth [*Plutella xylostella* (L.)], cabbage looper *Trichoplusia ni* (Hubner), green peach aphid *Myzus persicae* (Sulzer)], and Harlequin Bug *Murgantia histrionica* (Hahn). Diseases include downy mildew, alternaria leaf spot, cercospora leaf spot, white Spot, anthracnose, wirestem, bottom rot, damping-off, root rot (*Rhizoctonia solani*), yellows (Fusarium wilt), club root, black rot, and root-knot nematodes. As usual discussions will be focused on the main pests, encountered in the last three years by limited resource farmers engaged in the cultivation of collard greens for the Walmart Initiative. The diamond-back moth and downy mildew are the major pests that affect the production of collards in Alabama.

Diamond-back Moth (*Plutella xylostella* (L.)

The adult insect is a small, grayish-brown, slender moth which has very long antennae. Its common name comes from constrictions of a broad cream band along its back which gives it a diamond-like pattern. The insect's most rapid population growth occurs at temperatures greater than 80°F and at temperatures below 50°F, the larvae slow their feeding. Severe infestations of diamond-back moth may cause losses of up to 70 percent if uncontrolled. Damage to plants is caused by the feeding activity of the larvae which chew holes in leaves. Usually young larvae cause fenestration of leaves by feeding on one surface, leaving a thin layer or "window" of leaf epidermis. Feeding damage by larvae may serve as entry points for decay pathogens (Webb, 2013).

Integrated pest management practices such as regular scouting are particularly important for this pest because it has developed resistance to a range of insecticides in areas where serious infestations have occurred (Francis et al., 2005). It is recommended that fields be scouted weekly in a zigzag fashion in such a way as to cover all four quarters of a field; the pattern ensures that both interior and field borders are examined (Webb, 2013). Management methods include destruction of crop residue, use of transplants that are pest-free, avoiding the warmer months of the season, and use of cabbage as a perimeter trap crop. Natural enemies of this pest include parasitoids (*Trichogramma* sp.) and a number of fungal pathogens.

Downy Mildew

This disease, caused by the fungus *Peronospora parasitica*, can destroy a field of greens in a few days. Infected seeds and soils are common sources of inoculum for the pathogen. In wet weather, a grayish, fluffy mold develops in spots on the underside of infected leaves and the corresponding upper surface of the leaves begin to yellow and eventually develops into yellow to tan spots. Infected leaves on young plants may drop, and plants may eventually die but infected leaves on older plants usually remain attached to the plant. Early leaf infection may allow the fungus to enter the plants vascular system and turn it black. The fungus overwinters on seeds, on cruciferous weeds, on infected plant debris, in stored crucifer organs like cabbage heads and turnip roots, and on old tops left in the field. The disease can enter a field on infected transplants or wind-blown spores.

Management methods for this pest include plowing crop residue into the soil or baling the residue after harvest and eradicating cruciferous weeds (including volunteer crucifers) to eliminate potential overwintering sites for the pathogen. Rotating out of infected fields for 2 or 3 years, if feasible, aids in the management of this disease; extended crop rotations allow amount of inoculum (in this case, spore numbers) in the soil to decline before cultivating peas again. Overwatering and overhead irrigation both augur well for the incidence and development of the disease and should be avoided. A number of fungicides are effective against this disease but it is recommended that farmers switch between different classes of fungicides in order to forestall the development of resistance in the pathogen.

General Information on Weed Management and Use of Pesticides

Irrespective of the type of weed, there are some general recommendations that help to reduce the severity of weed problems on a farm. The main aim is to reduce competition between the crop and the weeds as well as to deprive other pests of shelter. Selecting the right time of the year for land preparation and planting activities is very important. Planting should be done as soon as possible after the recommended number of days have elapsed post-application of a pre-planting herbicide after land preparation; pre-emergence herbicides can also be used to prevent early competition of weeds with crops. It is extremely important to use the right herbicides that are effective against the weed species in a particular field. The objective of these practices is to give crops a head start in the race against weeds, and thus, a competitive advantage in the race for soil nutrients, water and other resources. Use of drip irrigation also helps to achieve selective supply of water to crops instead of weed species within and between plant rows.

This paper does not make any specific pesticide recommendations; rather, it advises that pest management specialists and Extension agents should be contacted for current information on pesticide recommendations. This is because pesticide resistance is a major problem and the best treatments today may no longer be effective in subsequent seasons or may be effective only in combination with other active ingredients. Farmers may also refer to the most current version of the Alabama Pest Management Handbook for information on recommended pesticides. Pesticide recommendations in the most current version of the Southeastern Vegetable Crop Handbook are also very helpful.

Use of Pesticides: Residues on Crops and Effects on Non-Target Organisms

Integrated Pest Management (IPM) is sometimes wrongly perceived as a set of practices that eschew or even forbid the use of pesticides. The discussions above show clearly that the use of pesticides is sometimes unavoidable in the quest to prevent economic damage, and thus, economic loss to the farmer. However, the use of pesticides entails costs, including environmental, health as well as financial. Use of pesticides should thus be based on a cost-benefit analysis that must involve all these different types of costs. Unfortunately environmental and health costs are usually overshadowed by financial costs in the pest management calculus. The environmental fate of pesticides and pollution of the environment (including water bodies) are of major concern. Improper use of pesticides and high pesticide residues in farm produce such as fruits and vegetables are also of major concern. A brief discussion of federal laws and regulations to ensure that the environment, consumers, and non-target organisms are kept safe will be very instructive, and this is the focus in the next two sub-sections.

Pesticide Residues on Crops

The 'Delaney clause', which disallows any cancer-causing chemical (carcinogen) on food for human consumption was added to the Food Drug and Cosmetic Act (FDCA) of the United States in 1958 (Pedigo and Rice, 2009). In 1991, the Pesticide Data Program (PDP) was initiated to collect data on pesticide residues in food (USDA-AMS, 2013). The program plays a very important role in the implementation of the 1996 Food Quality Protection Act (FQPA) which directs the U.S. Secretary of Agriculture to collect pesticide residue data on commodities most frequently consumed especially by children and infants (USDA-AMS, 2013). The PDP data are used primarily by the EPA and the FDA; the former to assess the dietary exposure during the safety review of existing pesticide tolerances (also called Maximum Residue Limits) and the latter (i.e., FDA) uses the data to assist in planning commodity surveys for pesticide residues from an enforcement/regulatory perspective. Produce, mainly fruits and vegetables, with the highest pesticide levels have become known as the "dirty dozen." The list includes apples, celery, cherry tomatoes, cucumbers, grapes, hot peppers, imported nectarines, peaches, potatoes, spinach, strawberries, and sweet bell peppers. Kale/collard greens and summer squash make it onto the list of the 14 most pesticide-laden food items in the U.S. Levels of pesticide residue in fruits and vegetables exceeding the EPA tolerance levels in 2011 are shown in Table 1 (Appendix).

High pesticide residues are generally due to a variety of reasons. Farmers who lack information and skills in IPM sometimes rely almost exclusively on pesticides for pest management; these pesticides are also sometimes used improperly. Pesticide application, when pests are most vulnerable, is one of the bedrocks of IPM; however, pests are sometimes targeted with the right pesticides but at the wrong time. Such use of pesticides against pests at a stage when they are capable of tolerating/withstanding their effects results in the use of application rates that far exceed the upper limits of the recommended rates in order to achieve appreciable reduction in pest severity. This results in high pesticide residues on fruits and vegetables. Pre-harvest Intervals (PHIs) which refers to the minimum period that must elapse between the last application date of a pesticide and harvesting of the produce is an important regulation that requires strict adherence; failure to do this results in high pesticide residues on food items; crops harvested within the PHIs tend to have high pesticide residues that are unhealthy for consumption.

Good record-keeping practices (including information on dates of pesticide application) help farmers to follow pesticide regulations, including those pertaining to PHIs. Improper calibration of pesticide application equipment, such as sprayers, and genuine errors in mixing of chemicals are also factors that sometimes contribute to high pesticide residues on produce. It is important to note that such mixing errors do not always result in an overdose of active ingredients but sometimes result in sublethal doses of pesticides which encourage the development of pesticide resistance. Hormoligosis is a negative effect which sometimes results from the use of pesticides; it is a phenomenon in which sublethal quantities of stress agents such as chemicals, antibiotics, hormones, temperature, radiation, and minor wounds, are stimulatory to an organism. This stimulation is achieved through increased efficiency to develop new or better systems to cope in a suboptimum environment (Abivardi, 2008). Simply put the application of sublethal doses of pesticides results in increased rate of reproduction of certain pests in their bid to survive the unfavorable condition.

Irrespective of the causes, resistance of pests to specific pesticides sometimes results in situations in which farmers feel compelled to use high quantities of the same pesticide or other pesticides (in that same class) with a similar pathway or mode of action instead of switching to a different class of insecticide as recommended. Sometimes this recommendation is not followed because farmers become overly attached to one product that exhibited phenomenal performance in the past. Lack of information on active ingredients may result in a switch to the same active ingredient that comes under different commercial names. It is extremely important to emphasize that over-reliance on a good pesticide from year to year usually leads to pesticide resistance and the connection of such resistance to high pesticide residues has already been established.

There are also instances when high pesticide residues are due to drift of pesticides from aerial sprays carried out on neighboring farms during windy conditions; in these instances non-target farms may not record the spray event which may lead to harvesting of crops prior to the expiration of the PHI. In addition, high rainfall periods are usually characterized by increase in the incidence and severity of fungal diseases. A number of these diseases are usually dealt with using a preventive (calendar) spray regimen. Such a regimen generally leads to increase in pesticide residues even if these do not reach or exceed the EPAs tolerance standards; when it comes to pesticide residues on food, lower is always better.

On the issue of pesticide residues that exceed the EPAs tolerance limits, Table 1 (Appendix) shows that metabolites of Captan fungicide on snap beans must be watched carefully based on the percentage of detections (9.4%) in the U.S. in 2011 that were above the tolerance limits. The relatively high percentage of detections of Bifenthrin (19%) on cherry tomatoes and the 5.7% detections each of Dinotefuran and Acetamiprid on sweet bell peppers deserve closer attention. Even though the percentage of detections above the tolerance limits is generally low, these figures provide an impetus to work towards further reductions in detections. It is important to note that the problem of high pesticide residues in food is partly market-driven because of the high demand for blemish-free fruits and vegetables; this results in a zero or "close to zero" tolerance for pests which in turn leads to excessive use of pesticides.

Unintended Effects of Pesticides on Target and Non-Target Organisms

Pesticides sometimes have adverse effects, including death, on non-target organisms. For instance, pesticides have been implicated in the rapid colony collapse disorder of bees. Yang et al. (2008) carried out studies using various concentrations of imidacloprid and found that as concentration was increased beyond a certain point, the ability of bees to locate their hives (homing ability) was compromised. This study is just one example of a number of studies that have pointed to various pesticides as possible contributors to the reduction in the native population of bees in various parts of the world. Such deleterious effects have been of major concern especially to environmentalists, agriculturists, and pest management professionals.

The inadequate native bee population in some locations has given rise to businesses which specialize in supplying pollinators including honey bees and bumble bees to farmers. Tuskegee University has been collaborating with one of such companies to supply bumble bees to watermelon producers involved in supplying Walmart with produce. The company has a chart with keys and legends that give customers (farmers) specific instructions pertaining to specific pesticides. The legend indicates that some pesticides are simply incompatible with the bumble bees, others require that the hive be closed prior to application and others require that the hive be moved out of the field for a number of days. The hives can be kept open for a few pesticides, especially some organic pesticides and products that are generally less toxic (characterized by short PHIs), most fungicides, and some herbicides. The hives also come with specific instructions on the alignment of the hives in relation to aspects of the sun and proper placement to avoid ant-induced vacation of hives.

Synopsis of IPM Activities, Pest Incidents, Pest Management Actions and their Impacts

An IPM training needs assessment was done using questionnaires that were administered to farmers at farmers' conferences and agricultural field days held at Tuskegee University in 2011 and 2012. IPM Training programs were subsequently tailored to address the needs that were identified during the IPM needs assessment phase. The major pests encountered by watermelon producers in Alabama included Anthracnose disease, downy mildew, and aphids. Major pests recorded on collard greens included diamond-back moth and downy mildew. Some purple hull pea growers reported major issues with purple hull pea curculio, stink bugs, and leaf-footed bugs. There were also isolated cases of downy mildew.

A number of IPM training programs (including pesticide safety training) were organized for farmers at the end of which interested participants took the necessary tests that led to the award of restricted-use pesticide permits by the Alabama Department of Agriculture and Industries. Farm-specific on-farm IPM training as well as hands-on IPM workshops are still ongoing to address the evolving range of pest management needs.

There has been a consistent improvement in pest detection among participating farmers in the last 3 years; the improvements have been in the areas of timeliness and accuracy of detections. Pre- and post-tests at workshops revealed major improvements in both the knowledge and confidence with which farmers identified insect pests. Change in knowledge on pest identification ranged from 19 to 70% (average of 44%) and change in confidence of the respondents ranged from 42 to 70% (average of 59%). Percentage increase in confident responses on pest management methods (including pesticides) ranged from 66-96% (average of 81%) and actual knowledge on these increased by 38%. The role of volunteer crops in encouraging pest problems was demonstrated in previous years; this helped participating farmers to redefine "weeds." This led to destruction of volunteer crops to avert pest problems. Purple hull pea farmers who encountered the purple hull pea curculio followed recommendations by siting new farms away from sites of known-infestation; in the case of crops already growing in areas known to be infested by the curculio, monitoring and preventive sprays (at the recommended times) were used. Crop rotation was another IPM tactic employed by purple hull pea farmers to manage the curculio. On-farm IPM training workshops for some beginning farmers were sometimes followed by scouting and monitoring exercises in the vegetable fields. In a few cases, these exercises were initiated by the farm owners/managers and led to the discovery of major pests on the farms.

As a result of financial investments in pollinators (bumble bees), farmers made sure they followed guidelines on the selection and use of compatible pesticides. The IPM team received a number of questions from farmers over the phone and in person on bee-compatible pesticides; the team members answered all the questions. Selection of crop varieties that have appreciable resistance to common and/or expected pest problems intensified in 2013 and has improved significantly in 2014 so far. Most of the collard green and purple hull pea growers have so far done a good job of not staggering the planting dates in such a way as to put different fields of the same crop right next to each other; this is to deprive pests the luxury of a new batch of hosts after their current host is destroyed and/or no longer attractive to the pest. Use of these and other IPM recommendations have generally resulted in fewer pest problems; there is, however, room for improvement. The few pest problems that were encountered in 2013 resulted in significant crop losses. A number of measures have been put in place in 2014 to ensure that participating farms prevent some of these pest problems or deal with them better to prevent economic losses. These measures include the selection of specific crop varieties based on the incidence and distribution of specific pests in the various regions where our target farms are located. Impact assessment exercises have also revealed that participating farmers understand the link between the health of plants and their tolerance of pests. Farmers participating in the Walmart Initiative have a good understanding of the pest management significance of plant nutrition and the availability of water.

Possible Effects of the Polar Vortex and other Extreme Environmental Conditions on Pest Severity and General Pest Management Recommendations for Future Seasons

The effects of weather on pest incidence and severity are well-documented. It is, however, very important to note that unusual weather phenomena can cause unusual pest problems. The incidence and severity of pests is usually partly a product of prevailing weather conditions as well as the severity and duration of winter and summer conditions in the preceding season. Unusual/extreme weather phenomena, such as hurricanes, sometimes result in the incidence of pests in regions where they were previously unrecorded. Pest problems tend to be more severe in such regions partly because of inadequate or complete absence of natural enemies of these pests. The inability of farmers to recognize early signs and symptoms of pests to which they are not accustomed, delays early detection/identification and exacerbates an already bad pest situation. For instance, the hot and wet summer conditions in 2013 resulted in anthracnose infestations in a number of participating watermelon farms; the incidence of this pest is very consistent with biology/ecology of the pathogen and its disease cycle. The polar vortex resulted in unusually cold weather, which can result in a very quiet early part of the season with very minimal or no pest problems, or which can result in a season characterized by infestation with pests that were not major problems previously.

Pest outbreaks occur partly because of a relaxation of one or more environmental constraints (such as natural enemies) on their growth, development and survival. Different organisms have different levels of tolerance to environmental extremes and a critical issue is the relative effect of such environmental extremes on pests and their natural enemies. If adverse effects on natural enemies far outstrip those on the corresponding pests, biotic constraints on pests are relaxed and pest populations begin to go up. However, extremely cold temperatures associated with the polar vortex may have relatively more adverse effects on specific pest populations so much so that the subsequent growing season will be quiet as far as that pest is concerned. The plan is to compare reported pest incidents this season to those recorded in previous and subsequent years (that were not characterized by such extremely low temperatures) to start the development of a predictive model for the effects of unusual weather phenomena in Alabama.

It is recommended that pest management professionals and county Extension agents emphasize pest advisories/forecasting tools and encourage farmers to use same. The incidence of anthracnose in 2013 was not a surprise given the high amount of rainfall, and high temperatures that characterized the growing season. Corrective actions in the form of draining/dredging water-logged fields, and preventive sprays help reduce the incidence and severity of the disease to a great extent. Status maps such as the one on cucurbit downy mildew give very useful information on the spread of the downy mildew which is very important in management decision-making. Given the fact that cost is a major factor in the pest management decision strategy, limited resource farmers benefit greatly from more precise information that helps them to select the most effective time-frame for preventive sprays. Such information is provided in epidemic status maps such as the one for the cucurbit downy mildew, subtitled: “Prepare, Predict, Prevent;” on that page is an apt description of the purpose of such advisories.

Given the considerable devastation caused by the purple hull pea curculio, areas of known infestation should be avoided for at least 3 years. Preventive sprays can be used if infestation is expected (based on proximity to areas where infestation has been reported). Such spray programs (at the very least) prevent a build-up of the insect pest in the affected area. It is critical that farmers and Extension agents pay an even closer attention to ensure that unusual pest problems are detected early and dealt with to prevent major devastation of crops. On-farm IPM training programs also need to continue to ensure that farmers, farm managers and farm-hands keep up with pest information and situations pertaining to their individual farms as well as those in surrounding areas. It is also important that the major IPM concepts and tactics be re-emphasized and the practices reinforced through hands-on training programs such as on-farm demonstrations. Peer-to-peer training of farmers on IPM will continue to be re-emphasized to ensure that it is practiced in its entirety and not reduced to a spray program. Periodic pesticide training programs will ensure that farmers get exposed to the most current information on the range of active ingredients that are effective against specific pests.

It is recommended that such training programs continue to highlight the entire range of available active ingredients and the importance of switching pesticides from time to time to prevent the development of pesticide resistance. As stated earlier, overhead sprinkler irrigation systems sometimes predispose plants to certain pathogens due to the presence of water on the plants, especially on the leaves. A number of well-resourced farmers, however, use them successfully without major disease issues partly because they follow recommended irrigation schedules and carry out preventive pesticide sprays. Clearly, the cost profile of scheduled pesticide spray programs is not suitable for limited resource vegetable producers. Drip irrigation, however, has a number of benefits in vegetable production including the efficient use of water and better management of weeds, if used properly. Proper use refers to the situation in which drip holes are made to coincide with plant locations and the water is turned on long enough to supply the immediate surroundings of the plant so that intervening spaces within and between rows receive as little of the irrigation water as possible.

Conclusion

Limited resource farmers in the Black Belt Region of Alabama have made major strides as far as IPM is concerned. The Walmart Initiative has provided an additional impetus to learn and adopt more of its practices. Profit margins in farm enterprises cannot be the only motivator in pest management decisions; environmental safety and health implications should be major factors in the pest management strategy. Farmers need to become very familiar with the cost-benefit calculations involved in decision-making processes pertaining to the use of pesticides. They must know when to cut their losses and when to apply pesticides to prevent worsening pest situations from reaching points that cause economic injury. The need to simplify such bioeconomic concepts even further to encourage higher adoption rates cannot be overemphasized.

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Appendix

Table 1. Percentage Detections of Pesticide Residues in Fruits and Vegetables in the USA (in 2011) and EPA Tolerance Levels.

Vegetable	Pesticide	Range of Values Detected	EPA Tolerance Level (ppm)	Percentage of Samples with Detections
Cabbage	Acephate (Insecticide)	0.033	Not listed	0.1
Cantaloupe	Acephate (Insecticide)	0.017 – 0.054	0.02	0.3
Frozen Spinach	Acephate (Insecticide)	0.21	0.02	0.6
Sweet Bell Peppers	Acetamiprid (Insecticide)	0.002 – 0.22	0.2	5.7
Cherry Tomatoes	Bifenthrin (Insecticide)	0.007 – 0.16	0.15	19.1
Snap Peas	Chlorfenapyr (Insecticide)	0.004 – 0.034	0.01	0.8
Frozen Spinach	Cyhalothrin (Insecticide)	0.026 – 0.092	0.01	1
Snap Peas	Cypermethrin (Insecticide)	0.038 – 0.27	0.1	4.4
Snap Peas	Deltamethrin (Insecticide) Includes Tralomethrin	0.020 – 0.19	0.05	1.5
Sweet Bell Peppers	Dinotefuran (Insecticide)	0.010 – 0.81	0.7	5.7
Sweet Bell Peppers	Fludioxonil (Fungicide)	0.04	0.01	0.1
Hot Peppers	Tetrahydrophthalimide (Metabolite of Captan Fungicide)	0.015 – 0.065	0.05	0.9
Snap Beans	Tetrahydrophthalimide (Metabolite of Captan Fungicide)	0.006 – 0.37	0.05	9.4
Snap Peas	Thiamethoxam (Insecticide)	0.003 – 0.12	0.02	2.2

Culled from the USA Calendar Year 2011 Annual Summary of the Pesticide Data Program (USDA-AMS, 2013)