Item No. 1 of 1

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SPATIOTEMPORAL INTERACTIONS AMONG MILE-A-MINUTE WEED, ITS NATURAL ENEMY, AND ENVIRONMENT

NON-TECHNICAL SUMMARY: Agricultural and forest landscapes in the United States face major threats by many invasive pests. Specifically, noxious invasive plants have caused considerable economic losses and environmental damage which are sometimes irreversible without adequate management of the threat in a timely manner. However, it is hard to accomplish efficient management of invasive pests and difficult to monitor when they are spread over large geographic areas (i.e. a landscape) due to complexities associated with the various biotic and abiotic environmental factors interacting and affecting invasive species. For the successful long-term management of invasive pests, it is necessary to predict the likelihood of establishing and spreading under different environmental and biological conditions at a landscape scale. Here, I propose a five-year research project to identify the landscape-level environmental and biological drivers of mile-a-minute weed (MAM) invasion and how these drivers interact with an introduced natural enemy, the mile-a-minute weevil (MAM weevil). In the recent past, MAM management has commonly relied on physical control (e.g. hand weeding and mowing) or chemical control (e.g. herbicides). However, biological control using an introduced insect has become a key management tactic since a classical biological control (i.e. introduction of the natural enemy from other countries) program was initiated by the USDA Forest Service in 1996 and field release in North America started in 2004.The goal of this project is to understand the ecological process of spatial interactions among MAM, MAM weevil, and environment. Overarching hypothesis of this project is that MAM and MAM weevil distributions in the landscape are determined by spatial interactions among the weed, weevil, and environment.To achieve this goal, I have defined two objectives to investigate:Objective 1. Spatial dynamics of MAM in the landscape: We will use unmanned aerial vehicle (UAV) for an aerial survey of MAM and percent weed coverage in the patch can be quantified based on the aerial image. Once aerial images are taken and downloaded from the UAV, a composite image will be generated. The composite image will be georeferenced to confer spatial attributes to the map coordinate system.Once the presence of all patches of MAM is confirmed and mapped, we will visit each patch of MAM and measure vigor of MAM by counting the number of fruit sets. The survey with the UAV and ground survey will be conducted every two months from April to October each year. Once the survey is finished, the boundary of each patch will be defined based on the survey above to create a time-series distribution map for MAM patches in each site. The time-series map information will be stored as a geo-relational database (i.e. layers) in a geographic information system.From the patch layers in GIS, we will extract landscape metrics to characterize the properties of patches. Landscape metrics describe patches based on area, length, edge, shape, aggregation, isolation, and diversity.To characterize the spatial structures of sampled variables (i.e. presence of the weed, percent weed coverage, and the number of fruit sets),

geostatistics and spatial analysis by distance indices (SADIE) will be used. The spatial data of patches will be converted to raster data (i.e. grid) for the analyses. Geostatistical analysis involves semivariogram modeling to quantify spatial structure and kriging to estimate values at unsampled locations to generate distribution maps. Thus, SADIE will be used to test the statistical significance of spatial aggregation, randomness, and uniformity.Objective 2. Spatial relationships of MAM and MAM weevil with environmental factors in the landscape: Because the weevil is specifically feeding on MAM, weevil sampling will be done only in the weed patches found in Objective 1. We will visit each patch of MAM and sample for weevil abundance and feeding activities using a quadrat. At least one sample should be taken from the center and one edge of a patch.In each quadrat, we will use three different ways to sample the weevil and its activities. First, we will directly count and record the numbers of adults and eggs on the leaves within the quadrat. Second, we will obtain an estimation of adult feeding amount in each quadrat by sampling damaged leaves. Third, we will exam nodes of MAM to recorded larval feeding activities. This sampling will be done at the same time when the ground survey for MAM is conducted. Investigating spatial relationships of MAM with surrounding vegetation is important because heavily damaged weed by the weevil can be quickly overtaken by surrounding plants, leading to death before the seed is produced. Goals for sampling vegetation in this project are two-fold. First, to characterize vegetation of the landscape-level habitats where the patches of the weeds are located. Second, to provide patch-level environmental and vegetation attributes for use in multivariate analyses. Two separate analyses will be conducted. First, we will compare five landscape metrics for MAM patches above with (1) presence/absence of weevil, (2) weevil density estimated from feeding signs, and (3) weevil count based on larval feeding damage on a node of MAM. Such comparison will determine what types of a patch (based on size, shape, and perimeter length) will be the most or least preferred by the weevil. Second, spatial associations between MAM and the weevil will be investigated with spatial association analysis by using SADIE, which compares the local cluster indices for each of any two data sets. Spatial relationships among MAM, MAM weevils, and environmental factors will be quantified by using SADIE for spatial association analysis. To identify key factors affecting spatiotemporal patterns of MAM and MAM weevil, multivariate analyses including nonmetric multidimensional scaling and multivariate regression will be conducted.

OBJECTIVES: The goal of this project is to understand the ecological process of spatial interactions among mile-a-minute weed (MAM), MAM weevil, and the environment. There are two main objectives in this project.Objective 1: Spatial and temporal dynamics of MAM and MAM weevil in the landscape;Objective 2: Spatial relationships of MAM and MAM weevil with environmental factors in the landscape.

APPROACH: Objective 1. Spatial dynamics of MAM in the landscape: We will use unmanned aerial vehicle (UAV) for an aerial survey of MAM and percent weed coverage in the patch can be quantified based on the aerial image. Once aerial images are taken and downloaded from the UAV, a composite image will be generated. The composite image will be georeferenced to confer spatial attributes to the map coordinate system.Once the presence of all patches of MAM is confirmed and mapped, we will visit each patch of MAM and measure vigor of MAM by counting the number of fruit sets. The survey with the UAV and ground survey will be conducted every two months from April to October each year. Once the survey is finished, the boundary of each patch will be defined based on the survey above to create a time-series distribution map for MAM patches in each site. The time-series map information will be stored as a geo-relational database (i.e. layers) in a geographic information system.From the patch layers in GIS, we will extract landscape metrics to characterize the properties of patches. Landscape metrics describe patches based on area, length, edge, shape, aggregation, isolation, and diversity.To characterize the spatial structures of sampled variables (i.e. presence of the weed, percent weed coverage, and the number of fruit sets), geostatistics and spatial analysis by distance indices (SADIE) will be used. The spatial data of patches will be converted to raster data (i.e. grid) for the analyses. Geostatistical analysis involves semivariogram modeling to quantify spatial structure and kriging to estimate values at unsampled locations to generate distribution maps.Although the semivariogram quantifies spatial dependence, it does not readily test the significance of spatial distribution patterns. Thus, SADIE will be used to test the statistical significance of spatial aggregation, randomness, and uniformity. SADIE measures the degree of clustering forming patches and gaps. Objective 2. Spatial relationships of MAM and MAM weevil with environmental factors in the landscape: Because the weevil is specifically feeding on MAM, weevil sampling will be done only in the weed patches found in Objective 1. We will visit each patch of MAM and sample for weevil abundance and feeding activities using a quadrat. At least one sample should be taken from the center and one edge of a patch.In each quadrat, we will use three different ways to sample the weevil and its activities. First, we will directly count and record the numbers of adults and eggs on the leaves within the quadrat. Second, we will obtain an estimation of adult feeding amount in each quadrat by sampling damaged leaves. Third, we will exam nodes of MAM to recorded larval feeding activities. This sampling will be done at the same time when the ground survey for MAM is conducted. Investigating spatial relationships of MAM with surrounding vegetation is important because heavily damaged weed by the weevil can be quickly overtaken by surrounding plants, leading to death before the seed is produced. Goals for sampling vegetation in this project are two-fold. First, to characterize vegetation of the landscape-level habitats where the patches of the weeds are located. Second, to provide patch-level environmental and vegetation attributes for use in multivariate analyses. Initially, we will conduct timed meanders of the sites in which the weed patches are located because this method has been shown to capture the greatest number of species for the lowest effort. Capturing accurate estimates of species richness is well known to be a function of plot size and effort expended.At each study site, we will establish the landscape-level vegetation sample using systematically-located, nested, fixed-area plots laid out in a grid (50 x 50 m) in each site (i.e. approximately 144 grids in each site). Tree height, dbh, crown area, and species will be recorded for each woody stem greater than 10 cm and crown area of trees will be estimated by measuring two perpendicular crown widths, the first being the longest dimension. A nested circular plot will serve to provide estimates of woody stem densities for stems of trees and shrubs with diameters less than 10-cm dbh. Plots will be systematically arranged at plot center and just inside the plot boundary at each cardinal direction.Three measurements will be made at or near bud-break, the second in mid-June, and the third during mid-August. The timing of these will be primarily to assess the changing nature of the herbaceous vegetation through the season. For the patch-level characterization of microtopography and vegetation attributes, we will estimate the centroid of each patch to serve as a plot center. The proximity of larger, woody vegetation to the patch will be measured using the point-centered quarter method wherein each of four cardinal quadrants the distance to the nearest woody stem and attributes of that stem will be measured. A total of five rectangular quadrats will be used to quantify environmental and vegetation attributes of the weed patches, one at plot center and the other four on the inside edges of the longest plot axis and its perpendicular. Topographic and vegetation measurements as described for the site-level variables will be made at plot center. These plots will be measured in the same temporal sequence as site-level herbaceous plots. To map the spatial variability of abiotic factors affecting mite-a-minute weeds and weevils, each site will be divided into ca. 144 grids (each grid is 50 m by 50 m). Soil type will be determined based on digital soil maps. Geographic variables will be collected in the first year of the project.Weather variables will be collected by installing a weather station and sensors in each site to monitor abnormal weather patterns that can affect MAM and MAM weevil. Sensors will measure air and soil temperatures, humidity, precipitation, wind direction and speed, and photosynthetically active radiation (PAR) throughout the project years.Two separate analyses will be conducted. First, we will compare five landscape metrics for MAM patches above with (1) presence/absence of weevil, (2) weevil density estimated from feeding signs, and (3) weevil count based on larval feeding damage on a node of MAM. Such comparison will determine what types of a patch (based on size, shape, and perimeter length) will be the most or least preferred by the weevil. Second, spatial associations between MAM and the weevil will be investigated with spatial association analysis by using SADIE, which compares the local cluster indices for each of any two data sets. Because successive sampling will be done at the same location, the association analysis also will be used to measure the temporal change of spatial distribution of MAM and the weevils. Distribution maps will be generated with ordinary kriging by using semivariogram parameters and then, cross-validation will be conducted to check the performance of semivariogram models in kriging. Spatial relationships among MAM, MAM weevils, and environmental factors will be quantified by using SADIE for spatial association analysis. Using the spatial association index and associated P values, any environmental factors positively or negatively associated with MAM and MAM weevil will be identified. To identify key factors affecting spatiotemporal patterns of MAM and MAM weevil, multivariate analyses including nonmetric multidimensional scaling and multivariate regression will be conducted. Our response variables (y) include MAM variables (i.e. vigor measured by fruit sets; % cover in patches).

PROGRESS: 2019/10 TO 2020/09
Target Audience:Findings from the research were presented at two entomology conferences where over 3,000 people attended. At the conferences, three presentations were given. In addition, the results of the project were presented at the Entomology Seminar Series at West Virginia University. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?One graduate student and one staff member were involved in this project and trained for conducting a multidisciplinary approach to solve pest problems in the forest ecosystem. How have the results been disseminated to communities of interest?The results of this project have been disseminated to the science community through two entomology conferences and one departmental seminar. Also, one manuscript was submitted for publication in a journal. What do you plan to do during the next reporting period to accomplish the goals?Objective 1: We will use unmanned aerial systems (UAS) for aerial surveys of mile-a-minute weed. The UAS also can hover at low altitude (i.e. 5-10 m above the canopy) over each patch to define the boundary of each mile-a-minute weed patch. Percent weed coverage in the patch will be quantified based on an aerial image. Our preliminary study showed that mile-a-minute weed can be readily detectible with UAS.From the patch layers in GIS, we will extract landscape metrics to characterize the properties of patches. Landscape metrics describe patches based on area, length, edge, shape, aggregation, isolation, and diversity. We will use the five key metrics below to describe characteristics and monthly changes of patches: mean patch number: Number of patches in the landscape, mean patch size, edge density:shape index, and patch density.These metrics will provide a quick description of mile-a-minute weed patches in each site. Specifically, these metrics will be helpful to understand how patches change throughout the year.

IMPACT: 2019/10 TO 2020/09
What was accomplished under these goals? Objective 2: A field experiment was conducted to compare the species composition of patches dominated by mile-a-minute weed(P. perfoliata) (dominated)to adjacent patches where P. perfoliata was not dominant (nondominated) within an environmentally homogeneous site that has been infested with P. perfoliata for at least five years. We hypothesized that dominated patches would have fewer native species and be less diverse than the nondominated patches and that the nondominated patches would be dominated instead by one or more aggressive native species or another invasive plant.We compared the species composition of P. perfoliata-dominated patches and adjacent nondominated patches in two topographically homogeneous sites using 20 paired plots, nonmetric multidimensional scaling, multi-response permutation procedure, and indicator species analyses. Richness and diversity were lower in the dominated plots, but both plot types had uncommon native plants present. The plot types differed significantly in composition with the nondominated plots, which were dominated by another nonnative invader, Microstegium vimineum, or a native weed, Ambrosia artemisiifolia. Documenting potentially interacting native and exotic species within an invaded landscape will help predict likely restoration success in response to targeted nonnative-invasive plant removal.

PUBLICATIONS (not previously reported): 2019/10 TO 2020/09
Type: Journal Articles Status: Under Review Year Published: 2020 Citation: Kim, J., C. Huebner, R. Reardon, and Y.-L. Park. Spatially-targeted biological control of mile-a-minute weed using Rhinoncomimus latipes (Coleoptera: Curculionidae) and an unmanned aerial system. Journal of Economic Entomology, in revision.
