**To the members of the Multistate Activities Committee:**

**The reviewer comments on our proposal were thoughtful and insightful, and we are grateful for the opportunity to resubmit our proposal to the NE Station Directors. The primary weakness revealed by this process was our vague and unclear description of the essence of our proposal. To be clear, we do not intend to develop new statistical models for weed seedling emergence; rather, we intend to adapt and validate existing, published emergence models for use in the Northeast and build a web-based, user-friendly decision support tool for use by extension educators, crop advisors, and growers. We have already begun this work using the equations published in Myer et al. (2004) with two years of emergence data collected in central New York State. Our proposed work will also include incorporation of hydrothermal equations from the WeedCast program into our model options, and collection of validation data from six states across the Northeast. We will then match the resulting suite of equations, modified for the Northeast, to an operational, continually updated weather (observations and forecasts) and soil moisture information database to create a tool that requires only location and weed of interest information to provide a real-time and short-term forecast for the percent emergence of that species.**

**Below we address specific comments raised by the three reviewers. We have modified the proposal to reflect the changes discussed below. Because this resulted in a substantial proposal revision, we did not cite individual changes in the text for the sake of brevity. Our responses are in bold text.**

**Reviewer Comments:**

**Reviewer 1:**

***Point 1a.*** As the authors of this proposal noted, WeedCast, an emergence model developed for the US Midwest, had never been widely adopted or used by farmers. Before embarking on such an ambitious project to develop a new weed emergence model for the NE region, I think user need should be carefully assessed. The authors of the current proposal claim that an unfriendly user interface was the main reason WeedCast wasn’t adopted widely. However, I am not convinced this is the only reason for lack of interest in this sort of tool, as no supporting documentation was provided for this claim. I think, as a first step, some fairly extensive grower surveys should be conducted to assess whether or not a weed emergence model would indeed be desired and used by NE growers.

**We have received verbal and written support for the value of an easy-to-use weed emergence prediction tool from extension specialists and educators who work closely with the grower community. We believe this decision support tool will be useful both for individual growers and for the extension/crop advisor communities. Attached to the revised proposal are letters of support from Dr. Julie Kikkert (Vegetable extension specialist Cornell Cooperative Extension), Sharon Bachman (Agriculture and Natural Resources Educator for Cornell Cooperative Extension of Erie County, NY), Dr. Emily Reiss (Director of Technical Services for Krehr Family Farms), and Jamie Cummings (Livestock and Field Crops Coordinator for NY IPM).**

***Point 1b.*** Although the authors didn’t mention it, the Weedometer, an online tool for estimating weed emergence, is currently available (http://weedecology.wisc.edu/weedometer/). The user interface for this tool is exceptionally simple – one need only input the weed species and one’s location. As a test, I chose common waterhemp with my location and the model prediction was extremely accurate. In fact, the Weedometer estimated the exact date of reported waterhemp emergence in my area. And yet, to my knowledge, this tool hasn’t been widely adopted, even though it has existed for at least 15 years. The reason can’t be that the interface is too difficult – nothing could be easier.

**The Weedometer is indeed an easy-to-use online tool that describes approximate first emergence, flowering, and seed set for a range of species based on growing degree days. However, the output provides the range of possible life stages of the plant rather than the estimated percent emergence on a given date, which is a different set of outputs from the emergence models and tools discussed in the proposal. While the geographic range of this tool is impressive, covering states from Colorado to South Carolina, it does not include any Northeastern states.**

***Point 2.*** Another first step would be to identify the main reasons WHY WeedCast doesn’t perform well in the NE region. A plethora of factors potentially contribute to weed emergence timing including genetics, temperature, soil moisture, soil chemical and physical properties, seed burial depth, tillage (including timing, depth, degree of inversion, and frequency), seed dormancy, and complex interactions among all these variables. The modeling process would be simplified if one focused on the factors that contribute MOST to emergence timing variability. I suspect that one of the biggest contributors to emergence timing variability might be genetic variability. Otherwise, WeedCast should have produced good predictions for the NE.

Therefore, another preliminary step might be to conduct reciprocal common gardens experiments at a wide geographical range of sites using many weed species biotypes. I suggest using both Midwestern and NE biotypes planted in a series of locations in both regions. Such an array of experiments would allow one to gauge WHY the WeedCast model performs poorly in the NE. This would be a starting place for developing a new model. Or instead of reinventing the wheel, one could work to parameterize and validate the existing model for the NE. I think that the Midwest regional group might be able to collaborate with the NE group to accomplish these objectives.

**Since writing the original proposal, we have done further investigation into the fit of the model we have been using, published in Myer et al. (2004), and the GDD equations underpinning WeedCast (Forcella 1998) with weed emergence data collected in 2016 and 2017 in central New York. In Figure 1, we compare pigweed emergence in 2016 with both the Myer et al. (2004) (black line) and WeedCast (red line) temperature-based model results. Neither curve is an ideal fit for emergence in this year, particularly at our more gravelly soil type site (Freeville, left).**



***Figure 1.*** *Pigweed emergence at two field sites in 2016 compared with Myers et al. (2004) (black line) and Weedcast (red and orange lines) model results using GDD accumulations based on 1 inch (red) and 2 inch (orange) depth soil temperatures.*

**We then incorporated the WeedCast moisture limitation metric into the Myer et al. (2004)- based model, results of which are shown in Figure 2 (below) for pigweed at the gravelly loam site. Addition of the moisture limitation to the WeedCast equation (not shown) did not affect the output of that model, as the moisture limitation occurred after the model predicted near-complete emergence for pigweed. Incorporation of WeedCast’s moisture limitation successfully adjusted the shape of the Myer et al. (2004)-based model to better fit the observed data, but emergence was still faster than the model predicted.**



***Figure 2.*** *Comparison of modeled percentage emergence of pigweed including the NRCC model simulation accounting for limited soil moisture (solid red) in addition to the original NRCC model simulation (dashed red) at the Freeville Research Farm during 2016 (red line) with observed emergence in tilled (green) and no-till (blue) trial plots.*

**More work is needed to fine-tune the existing models and a better understanding of why the models over-and under-estimate observed emergence results will be a key component of the work. We propose to collect three years of emergence data across six Northeastern states, and use the resulting data to test these two models to determine which one may be most accurate at various latitudes, and under different soil types and weather conditions. We will then modify the equations to best fit the observed data, incorporate soil type as a variable for soil moisture, and publish the results. As we collect these data, we anticipate that patterns will emerge to suggest potential causes for discrepancies between sites. For instance, within our very limited existing data set, the largest discrepancies appear to be based on the calculation of soil moisture in different soil types. This is something which WeedCast is able to incorporate and is where we plan to focus our next efforts. We would welcome the opportunity to learn from the developers of WeedCast as we use the recently available soil moisture model and Northeastern soils data to incorporate similar functionality into the Northeastern tool.**

**As the data generated by this proposal produce new hypotheses and questions, further research can be proposed to refine model fit and expand the range of weeds available in the decision tool. We believe that collecting the initial Northeastern weed emergence data set, finding the best model fit possible with existing emergence equations, and pairing the resulting equations with the recently developed soil temperature grids and forecasting tools for the Northeast are solid first steps in this process, and a good fit for the mission and the scope of Multistate projects.**

***Point 2b.*** If genetic variability underlies much of the variability in weed emergence timing, how would weed biotype information be incorporated into an emergence model? One would need to know which weed biotypes occur at a given location. Could these biotypes be identified via DNA analyses then mapped? This alone would be an enormous undertaking.

**We agree that genetic variability may be a critical factor in emergence timing. Dr. DiTommaso is currently participating in a country-wide collaborative project on Johnsongrass (*Sorghum halepense*) that aims to determine how different biotypes of this aggressive perennial weed across the invaded region of the US impact its growth, phenology, phenotypic plasticity and winter survival. It is indeed an enormous undertaking, and this type of research is outside the modest scope of the proposed Multistate project.**

***Point 2c.*** Another issue with the NE proposal is that no methods are presented to account for genetic variability. No mention was made of growing various biotypes in reciprocal plantings. In fact, a few species would be grown by only one researcher at one site. This proposed approach will have limited success if genetic variability is a big component of emergence timing variability. Furthermore, the proposal authors claimed that herbicide resistance management would be enhanced by an accurate weed emergence model, and yet few of the species they chose to focus on are major resistance problems. However, I understand that researchers are reluctant to introduce new species to their respective locations.

**Given the funding level of the multistate proposal and collaborator resources, we have opted not to investigate genetic variability as a specific cause of variation in emergence timing. We instead propose to use growing degree days and soil moisture models to match existing empirical emergence models to observed emergence across the Northeast, leaving the ecological factors underpinning regional emergence differences for future efforts.**

**We selected our limited suite of weed species based on the lists of top five problematic weed species contributed by each participating state partner. Common lambsquarters, large crabgrass and redroot pigweed were the most commonly listed (three or four of the six states), while common ragweed appeared on most northern lists and morningglories appeared on most southern lists (Fig. 3). Three states specifically mentioned Palmer amaranth as an issue, but are unwilling to introduce it to their research farms. We believe that this suite of species is a reasonable starting point to test the fit of existing model equations across the region. To increase the local relevance of the project for our collaborators, we also included weeds of interest in a particular state (for instance, wild radish in Maine or Italian ryegrass in Virginia). Although the resulting models for these state-specific weed species may not have a strong fit across the Northeast region, they will be of value to the state in which they are a problem; in cases where the weed of interest is not covered by Myer et al. (2004) or Forcella (1998), we will use the same functional forms of the equations in Myers and Forcella to fit parameters representative of the emergence data collected for these species. In the final decision tool, these weeds will only be available in the region where the models were fitted.**

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| --- | --- | --- | --- | --- | --- |
| ***Top Five Problematic Weeds in your State*** | | |  |  |  |
| **Maine** | **New York** | **New Jersey** | **Delaware** | **Maryland** | **Virgina** |
| **Crabgrasses** | **Common ragweed** | **Common lambsquarters** | **Common ragweed** | **Common lambsquarters** | **Palmer amaranth (pigweed species)** |
| Hairy galinsoga | **Pigweeds** | **Common ragweed** | **Common lambsquarters** | horseweed | **Common ragweed** |
| **Common lambsquarters** | **Common lambsquarters** | Hairy galinsoga | **Redroot pigweed** | Giant foxtail | **Morningglory species** |
| **Redroot pigweed** | Foxtails | Goosegrass | **Large crabgrass** | **Redroot pigweed** | Italian ryegrass |
| Wild radish | **Large crabgrass** | **Morningglory (ivyleaf/pitted)** | **Ivyleaf or pitted morningglory** | **Large crabgrass** | Johnsongrass |
|  |  | Yelow nutsedge for veggies | | |  |

**Figure 3.** **Top five most problematic weed species reported by Multistate collaborators in the five participating states. Species in bold were selected for study.**

**Of the five species selected for this Multistate proposal, three species (common ragweed, common lambsquarters, and redroot pigweed) currently have herbicide-resistant biotypes in the participating states.**

***Point 3.*** The proposal lacks sufficient detail describing exactly how the proposed model would be developed, parameterized, and validated. All three of these steps are required to develop and test a model. This lack of detail suggests that the participating researchers may be inexperienced in regard to developing emergence models. To this point, I think that more progress could be made by collaborating with the researchers who developed the Midwest models. Instead of reinventing the wheel, progress could be made by building on and improving existing models.

**As mentioned, our intention is not to build new weed emergence models, but rather to fit existing models to Northeastern emergence data, and incorporate weather and soil data sets to create a user-friendly, web-based decision support tool for weed management in the Northeast. Our collaborators at Cornell University’s Department of Earth and Atmospheric Sciences have developed many such tools that are currently available from the Network for Environment and Weather Applications (NEWA) (**[**http://newa.cornell.edu/**](http://newa.cornell.edu/)**), including models for predicting potato late blight, downy mildew, tomato diseases, apple maggot, cabbage maggot, and more. The weed ecological knowledge necessary to make informed decisions on fitting existing models to the data set will be provided by the many weed ecologists partnering on this project including Dr. Moshen Mesgaren (UC-Davis) who has especially strong weed germination and emergence modeling experience.**

***Point 4.*** Overall, I think that this proposal addresses a potentially interesting and relevant issue. However, in its current state the proposal demonstrates a lack of logical thinking about how best to tackle the problem. I suggest a major revision, and reconsideration of the main objectives.

**We hope that our responses to the reviewer’s thoughtful comments have provided sufficient improvement in our description of the project to merit their approval.**

**Reviewer 2:**

*Reviewer comments that do not offer points for revision have been deleted for the sake of brevity.*

***Point 5.*** In addition to weather forecasts at high spatial resolution, the weed emergence model will need to incorporate spatial information on soil type, as well as information on relationships among weather, soil type and soil conditions. The proposal indicates that soil types have been considered in the development of preliminary data, but it is not clear how the eventual emergence model will provide end users to customize soil type settings. Although specifics are not provided, the proposal states that researchers in the Department of Earth and Atmospheric Sciences at Cornell University will integrate soil models. I am confident that these researchers will be able to integrate soil maps and models, but because procedures are not provided, I scored "achievable goals/objectives" as "good".

**Thank you for pointing out this area for improvement. We hope to incorporate existing soil spatial data into the model, and use metrics within the SSURGO database to more accurately reflect soil moisture in a given location. We have incorporated this suggestion into the proposal.**

**Reviewer 3:**

***Point 6.*** It would be valuable for PIs to pay attention to differences in emergence due to environmental factors and genetic differences among populations. Without understanding the influence of these two factors on seedling emergence, it is difficult to generate seedling emergence predictive models that have local and regional accuracy.

**We agree that these factors are critical to weed emergence. We hope to capture environmental factors through temperature and precipitation data and through soil moisture models. With the limited budget proposed here, we are not able to effectively study genetic variability across the Northeast (or between the Northeast and Midwest as per Reviewer 1 comments). We believe that adapting existing emergence models to observed weed emergence data will provide a reasonably good fit for our region, and hope that the data collected through this project will inform future projects focused on determining which genetic and environmental factors drive the observed emergence differences across the region.**

***Point 7.*** The selected species, although considered weeds, are commonly not the ones driving weed management decisions in the proposed area with the exception of common ragweed. PIs should explain better how information about emergence timing of these species will drive the overall decision making for weed control.

**Please see comments in response to point 2c.**

***Point 8.*** There are existing emergence and dormancy/germination models for common ragweed, redroot pigweed, and johnsongrass. The PIs made no reference to those models, or how their model will incorporate that information or how their model is better than existing ones.

***Point 9.*** There is no mention of how the models will be validated. This is a common mistake in "modeling" projects. Just describing the observed emergence based on thermal or hydrothermal time does not generate a predictive model. Assessing the robustness of the model against independent data, preferably generated form different locations and with different climatic conditions is important.

**Points 8 and 9 speak to the main weakness in our original proposal, in that we failed to clearly explain that our focus was on refining existing emergence models. We are using existing models and validating them with newly collected in the Northeast. These data will cover six states and three years, and be collected under different climatic conditions.**

Point 10. It is a concern that most of the PIs have no expertise on weed emergence modeling. Dr. Mesgaran is part of the project providing some help with experimental design, but the rest of the PIs seem to be limited to collecting emergence data. It is not clear who will be doing the complicated task of developing the model.

**Please see our response to Point 3.**

***Point 11.*** It is greatly appreciate that this is a regional project covering a large extension. This could generate very valuable data to understand differences in emergence across locations. Although, it is also positive that the PIs propose to work with growers to test the draft model and get feedback about its value and use, my experience working on seedling emergence modeling is that it is very important to have a fully validated model before encouraging their use by growers. Having an inaccurate model will discourage growers from using these tools in the future. PIs should develop a strategy for avoiding this issue.

**We are grateful for this important feedback. We have revised the proposal to use a limited number of extension and grower partners in Year 2 to validate the decision tool and provide feedback, and will wait to advertise the tool until we have a more complete and fully validated product in Year 3.**

***Point 12.*** There are multiple citations with the reference missing.

**Thank you; this has been addressed.**