Participatory Screening of Broccoli Varieties

For Organic Systems in Western North Carolina:

Phase II- On-Farm Trials

(2015 Field Season)

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1. Project Summary

Organic vegetable farmers report that variety selection is a high research priority to ensure their success. Our 2015 participatory organic broccoli variety trials built on the project we started in 2012. Replicated field studies were completed in the organic unit on a research station in 2012 and 2013 successfully involving farmers in variety selection and evaluation throughout. In 2014 and 2015 we selected the six top performing varieties from the previous studies and evaluated them on the research station and on organic farms in western North Carolina. Participatory approaches used to screen these varieties involved farmers in project planning, implementation, and evaluation. Facilitating a whole systems approach for organic research projects was also focused on.

Based on the results from the 2012-2015 studies, for organic summer broccoli production in western North Carolina, the best performing crown cut varieties for yield, quality, disease resistance, and insect tolerance are Bay Meadows, Packman, Green Magic, and Umpqua. Additional varieties identified or bred through the complimentary multi-state, federally funded Eastern Broccoli Project for heat resistance are flagged as appropriate for WNC organic broccoli growers as well.

A field day and harvest workshops brought western North Carolina organic broccoli stakeholders together to evaluate the varieties in the 2015 trials on the research station and on-farm trial locations. Outreach of the results and potential impacts of these studies were made through a winter broccoli meeting and presentations by researchers and experienced broccoli growers at conferences and meetings in the region.

2. Introduction to Topic

An industry survey by Carolina Farm Stewardship Association (CFSA) in 2013 revealed a large market demand for organic broccoli in the Southeast. Due to higher elevation and cooler temperatures, organic farmers in western North Carolina are in a unique position to produce broccoli throughout the summer months when it is too hot to produce it in most other areas in the Southeast. In surveys we conducted, organic farmers reported that variety selection is a high research priority to ensure their success. Broccoli has traditionally been bred for and grown in Southern California, with over 95% of all U.S. broccoli produced there. There are 293 local broccoli growers listed in the 2015 Local Food Guide of the Appalachian Sustainable Agriculture Project, an increase from 179 in 2014. More than half are listed as certified organic or organic but not certified. In 2015, we concluded the first five years of a multistate project funded by the USDA-Specialty Crops Research Initiative, titled “Developing an Eastern Broccoli Industry”. The goal of the Eastern Broccoli Project was to foster enough broccoli production year round on the East Coast to supply local markets, instead of shipping it from the West Coast. New heat tolerant varieties developed for Eastern growing conditions were screened on research stations and farms from Maine to Florida, in conventional production systems. It is important to also screen varieties under certified organic growing conditions since the varieties that perform the best in conventional production systems might not perform as well in organic systems. It is

also important to have participation from regional growers and to include on-farm variety screenings.

The participatory organic broccoli project was a four year project funded by three OFRF grants. The first two years consisted of large replicated trials conducted on certified organic land on a research station in western North Carolina. Growers were involved in selecting and evaluating the varieties each year. We refer to these studies as the mother trials. In 2014 and 2015 the growers selected the top six varieties from the mother trials to test in baby trials. These were conducted on certified organic farms and on the certified organic land on the research station. This report covers the 2015 baby trials.

3. Objectives Statement

Objective 1: Identify the best broccoli varieties adapted for summer production on organic farms in western North Carolina.

Objective 2: Use participatory varietal selection to facilitate farmer involvement in organic farming systems research.

Objective 3: Contribute to a model for incorporating a systems approach to organic research projects.

4. Materials and Methods

Baby Trials. Baby trials brought the top performing varieties from the 2012 and 2013 mother trials to organic farms in the region. Three organic farms in the region hosted on-farm 'baby' broccoli trials in 2015. A fourth baby trial was managed on the Certified Organic Research Unit at the Mountain Research Station in Waynesville, NC. Each of these four sites served as a replication 'by location'. Another grower, late to join the project, hosted a 'mini baby trial' in 2015 for collecting additional insect and disease data. Plot size and management was consistent for all replicates/sites to produce comparable results. Different locations over a range of elevations were selected to include a range of micro-climate conditions spanning the western North Carolina region (Figure 1).

Treatments were five varieties chosen by farmers and researchers based on the results from the 2012 and 2013 research station mother trials. Packman remained the control variety, consistent with the 2012 to 2014 studies. The other varieties were Bay Meadows, Gypsy, Green Magic, Belstar, and Umpqua (an open-pollinated variety) (Figure 2). One replicate of each variety was grown out at each of the four locations. Thus, the experimental design was a randomized design with four replications (Figure 3).

Seeds were provided to one baby trial host (Site 4), and transplants of the six varieties provided to all other locations. For the research station and locations who received transplants, the six broccoli varieties were seeded on May 13, 2015 in a certified organic greenhouse on the Mountain Horticultural Crops Research Station in Mills River, NC (Figure 1). A soilless mix, McEnroe Organic Potting Premium Lite mix was used in new 98-cell trays. The transplants were fertilized twice with Neptune's Harvest Fish and Seaweed emulsion. Transplants were grown in

the greenhouse for four weeks (Image 1), hardened off, and transplanted into the fields in mid to late June, 2015 (Image 3).

Broccoli was grown using the standard organic production methods of the region in accordance with the National Organic Program. The farmers were encouraged to use raised beds with drip irrigation and white-on-black plastic for optimal summer production (Image 2). Two of four baby trial sites utilized white-on-black plastic mulch, the other sites planted on bare ground raised beds (Images 10 and 13). Broccoli was grown in double rows on raised beds spaced 5.5 foot center to center. Each trial included the six varieties with 80 plants per variety, with an in-row spacing of 8 to 12 inches and between row spacing of 12 inches (Image 3), consistent with 21,780 to 32,670 plants per acre.

Cultivation and mowing between rows were used for weed management. Fertility included standard commercial (OMRI approved) organic fertilizers. In some locations compost and crop rotation/cover crops served as nutrient sources. Additional boron was incorporated as Borax or sodium borate at all sites at a rate of 2 pounds per acre.

Row cover was recommended where applicable and farmscaping used at all locations to provide beneficial insect habitat and reduce pest pressure. Row covers were minimally used at one 2015 baby trial site as a physical barrier to flea beetles and harlequin bugs. Chinese mustard was planted as a trap crop for flea beetles and harlequin bugs at the research station site (Images 8 and 9). Farmscaping seeds were supplied to all growers and grown as beneficial insect habitats at three of the four baby trial sites (Image 5).

Participatory Research. Organic farmers in western North Carolina helped select the top performing broccoli varieties through participatory evaluations of the 2012 and 2013 research station mother trials. The second phase of our participatory variety selection evaluated the best varieties from the 2012 and 2013 research station trials in grower field trials to further evaluate variety performance. This phase is referred to as 'baby' trials, as compared to the research station 'mother' trials. Participatory variety selection has shown that results from on-farm baby trials align with the results from research station mother trials, and that the efficacy and adoption of new variety selection for growers increases with on-farm trials following on-station participatory research.

Cultural practices were developed during the course of the mother trials, and adapted to each farmer's existing management for on-farm baby trials of 2014 and 2015. Management for baby trials was agreed upon prior to planting.

Input from growers on successful outreach tools and dissemination of results encouraged researchers to have more hands on, on-farm education components to the project, and in-person meetings and presentations to share results and challenges in 2014 and 2015. On-farm baby trial hosts shared their experiences and challenges throughout the growing season via email and phone correspondence, farm visits, and grower meetings. Information was exchanged amongst researchers and growers as issues surfaced, particularly regarding insect and disease pressure. Management response to these issues was applied as consistently as possible among the baby trial sites.

Researchers visited the on-farm trials to assist the farmers in observing and measuring selective traits consistent with the participatory research station trials of 2012 and 2013. Data recording worksheets for insect and disease pressure as well as qualitative and quantitative harvest records were provided to the farmers (Appendix III). Each variety was evaluated based on the traits of interest finalized in 2013 by the growers and industry.

Post-harvest Handling and Marketing. Researchers assisted with field management preparations, planting dates, insect, disease, and fertility trouble shooting, and were present for harvests and post-harvest handling inquiries. Growers and Cooperative Extension Agents were invited to harvests at three of the baby trial locations. The fourth location (Site 3) did not produce 2015 results due to disease.

Harvest criteria were broccoli crowns of 4 to 5 inches in diameter with 3 inches of stem for 2015 baby trials (Image 19). Side shoots were also harvested and marketed at some 2015 trial locations. Rapid cooling was practiced at the trial sites packing for wholesale. After packing in boxes, the broccoli was topped with ice and transferred to a cooler. The broccoli was packed in 20 lb. boxes, 1 1/3 bushel size. A majority of the broccoli was direct marketed.

Marketing assistance was provided by researchers as a complementary component of the economics and marketing aspects of the Eastern Broccoli Project. Local buyers, growers, and researchers met throughout the baby trials to discuss opportunities and challenges. Local buyers have been very accepting of broccoli available during the summer harvest window, and assisted with updating cooling and packing preferences for crown cut heads. Progress was made towards narrowing gaps created with additional cooling needs for summer broccoli.

Systems Approach to Organic Research. Ongoing efforts to provide valuable insight to completing organic systems research continues. We developed an organic broccoli production system, instead of an isolated variety trial. Over the past four years we tested several cultural practices that organic farmers are already using or have considered using. We incorporated and refined production guidance with more practices in the research station baby trial of 2014; and continue to encourage cooperating and regional organic farmers to use those we evaluated in the baby on-farm trials.

Many organic growers were skeptical about our ability to produce broccoli during the middle of the summer because they had not been successful due to heat. These growers reported using the same varieties and cultural practices (bare ground, mono-crop planting, often with overhead irrigation) that are used for their spring and fall plantings. Summer production of broccoli is more difficult and requires a more integrative approach. This was a great opportunity to test existing varieties and improved cultivation methods and demonstrate the success of a more integrated systems approach to organic research.

Through our 2012 and 2013 mother trials as well as through the Eastern Broccoli Project conventional studies, we were able to demonstrate that growing the appropriate varieties on raised beds with white-on-black plastic and drip-irrigation resulted in high yields of quality broccoli with good flavor. There has been an increase in use of white plastic with area broccoli and vegetable growers, a form of season extension, that small farms have hand planted a second or third crop (different species) into following broccoli.

Using row covers for preventive insect control was evaluated throughout the 2012 to 2015 research projects, and found to be beneficial. Heavy flea beetle attacks that often occur during the summer season were prevented by using row covers for the first few weeks after planting in mother trials and 2014 baby trials. While not found to be economical, row covers remain a useful tool along with other integrative practices for preventative insect control; yet may pose additional challenges for growers in high heat transplant windows. Other insect problems, such as cabbage worms and aphids, were reduced by incorporating farmscaping with flowers and herbs within the field. Preliminary observations also revealed a trap-cropping like influence of particular farmscaping species, where the top broccoli pest of the region, the Harlequin bug, was drawn to Mexican marigold first.

Baby trial hosts were provided seeds for farmscaping and production guidelines for trap cropping options. Farmers were encouraged to establish farmscaping and trap crops in advance of broccoli planting to help reduce insect pressure and provide the benefits of a more complete organic farming system. A portion of farmscaping was grown within select on-farm trial areas as recommended by farmer-collaborators and researchers. Farmscaping included coreopsis, nasturtium, calendula, dill, tulsi, sunflower, borage, hyssop, and Mexican marigold for planting around the research plot areas. Thyme, oregano, tulsi, and calendula were planted between plots on some sites for additional beneficial insect habitat close to the crop, such inter-planting appeared more beneficial than buckwheat intercropping utilized in 2014 baby trials (Image 7).

Trap cropping was demonstrated in 2014 and 2015 baby trials at the research station location. Chinese mustard was confirmed to be preferred by flea beetles and harlequin bugs to broccoli (Image 9). When planted in proximity to and in advance of broccoli transplants, it serves as a feast for arriving pests (Image 10). Direct seeding four weeks ahead of transplanting, the leaves are large enough to welcome pests as soon as broccoli is in the ground (Image 16).

Data Collection and Evaluation. Previously, farmers identified head color, bead size and uniformity, head smoothness, head shape, firmness, overall quality, defects, yield, side shoot yield, and taste as traits to evaluate in 2012 for crown-cut broccoli. In 2013 insect and disease resistance traits and seedling vigor were monitored for all varieties based on farmer input. 2014 baby trials added additional quality traits and options for various end markets (head size, uniform maturity and plot uniformity, and average weight of head).

2015 baby trials refined data collection points for ease and comparison across all sites. Fewer data traits evaluated in a traditional research format and more observations and discussion of cause and effect were focused on along with the top important traits for variety evaluation (quantity, quality, insect and disease susceptibility, and response to management). More freedom in evaluating the entire broccoli system (and farm in some cases) while maintaining comparable data for analysis showed to be beneficial to growers and researchers, as well as more practical to disseminate amongst stakeholders and reach growers more efficiently.

In 2015 researchers evaluated varieties for the baby trial on the research station and the three cooperating organic growers evaluated the other baby trials with support and data collection materials provided by the researchers (Appendix III). Harvest quantity was evaluated through head counts and weights of marketable and unmarketable heads (and reason for unmarketability)

per plot. Harvest quality was evaluated at harvest through overall quality and those traits important to the grower. Side shoot production was assessed by an agreed upon rating for those farmers who harvested side shoots. Insect and disease pressure were evaluated via standardized ratings of vigor, insect damage (cabbage worms, flea beetle, harlequin beetle), and disease pressure (Alternaria and other). Many observations and pictures were recorded for the baby trials throughout the season regarding these traits, as well as to evaluate management practices and differences by location. Researchers recorded additional data at the research station replicate including specific data on additional quality traits and observations attributed to farmscaping and trap-cropping.

Data Analysis. 2015 baby trials were analyzed with the GLIMMIX procedure in SAS where sufficient information was available. The effect of treatment was tested on harvest quantity, total yield, head color, head smoothness, head firmness, bead size, bead uniformity, overall quality, harlequin bug resistance, flea beetle resistance, and Alternaria resistance. Replication was considered as random effects. Restricted maximum likelihood estimation technique was used with the Satterthwaite degrees of freedom. Baby trials also relied on observation and pictures to communicate results.

2014 baby trials are presented and compared to 2015 results when sufficient information for statistical analysis was available. The 2014 baby trials were analyzed using the MIXED procedure in SAS for data that were sufficient for statistical analysis; the effect of treatment was tested on crown harvest quantity, harvest quality, side shoot yield, total yield, head color, head smoothness, head firmness, bead size, bead uniformity, overall quality, insect and disease resistance, and flaws due to heat stress. Replication was considered as random effects. Appropriate data were tested for homogeneity of variance by examining residual vs. predicted plots and for normal distribution of variance using the UNIVARIATE procedure to examine quantile-quantile plots.

5. Project Results and Discussion

The 2015 baby trial results are discussed separately and combined with 2014 baby trial results where analysis was comparable and significant. Please see referenced Appendixes for figures and images illustrating results from the trials, as well as data collection materials used by researchers and participants.

Variety results. The top performing broccoli varieties selected for 2014 and 2015 baby trials from the results of the 2012 and 2013 mother trials were Umpqua, Belstar, Bay Meadows, Green Magic, Gypsy, and the former industry standard Packman. 2015 was a high heat summer, with extreme heat waves at baby trial plantings followed by heavy rains and additional heat waves; 2014 was a hot and dry summer season (Figures 4 and 5). Insect pressure was high from the beginning of the 2015 summer season, even in our complementary conventional trials. Disease pressure was normal in 2014 and heightened in 2015, likely due to high rainfall. These two years provided great opportunities to select heat resistant and adaptable existing varieties for western North Carolina organic broccoli production.

Available full data from three to four locations are presented for a majority of the results, and formal data from at least two locations presented for all results. Additional observations and information from all baby trial sites are included in the discussion. Where statistical analysis was not possible because of lack of replication in some of the 2014 and 2015 baby trial studies, averages are presented and noted as 'raw data' on figure titles.

Quantity. Yield is a top priority in variety selection for growers and easy to observe on farm. Side shoot performance and duration of harvest are additional considerations for organic growers. Baby on-farm trials assessed the number and weight of broccoli heads of each variety per plot, and noted reasons for unmarketability where applicable.

In the 2015 baby trials, average yield was greatest for Packman, followed by Green Magic and Umpqua. Gypsy, Bay Meadows, and Belstar had the lowest average yields across all sites in 2015 (Figure 7). Some varieties stand out in different research years, likely due to weather and management. 2015 results for Bay Meadows were inconsistent with previous year's research. 2014 and 2015 raw data from the research station location are provided for combined year average yields (Figures 8 and 9). Bay Meadows had the greatest yield of marketable heads produced in the 2014 summer season, followed by Green Magic, Belstar and the control variety Packman. Umpqua and Gypsy yielded the lowest in the 2014 baby trials. 2014 and 2015 combined yield data show Packman, Bay Meadows, Umpqua, and Green Magic with the highest yields when grown in the summer season. Gypsy and Belstar had inferior yields (Figure 9). **Assessing performance over 4 years of mother and baby trials, Packman, Bay Meadows, Green Magic, and Umpqua were top performers for yield.**

Side shoot performance was evaluated in 2015 baby trials through a standard rating. No significant differences were found in 2015. In 2014 baby trials, average yield for side shoots was highest for Umpqua, yielding twice the weight (or more) than other varieties. Packman yielded the second largest side shoot harvest. Bay Meadows also had good side shoot production in 2014 baby trials. (Data not shown).

Varieties that mature first are sought for their short time in the field, especially in the summer season where heat waves at harvest can limit growers to a short harvest window before crowns loosen and bolt. In 2015, Umpqua and Packman were the first varieties to mature. Packman also retained the longest harvest window. At three baby trial sites in 2014, Umpqua was the first variety to be harvested; closely followed by Packman and Green Magic, then Bay Meadows at all sites. Belstar was the latest maturing variety of the 2014 baby trials. Umpqua and Packman are top choices for minimal days to harvest.

Quality: Uniform bead and head uniformity/smoothness are indicator traits of heat resistance in broccoli. These traits are measured on a scale of 1-5 (five is best), with a rating of three or higher considered marketable. Flaws such as cateye (Image 26) and bolting are characteristic observations of heat stress in broccoli.

Green Magic and Packman performed well for uniform bead in 2015. Contrary to 2014 and previous results, Bay Meadows received lower than marketable ratings for uniform bead in 2015 (Figure 10). In 2014 baby trials, Bay Meadows had the most uniform bead, followed by Green Magic and Umpqua. Packman and Gypsy also had good bead uniformity and were considered

marketable for that trait (rating of 3). Combined baby trial data from 2014 to 2015 show Umpqua, Packman, and Green Magic had the best uniform bead (average rating of 3.5 and higher) across five locations and two years (Figure 11).

Packman received a slightly higher overall marketable rating in 2015 from the average of all sites (Figure 12). In 2014 the industry standard Packman had the best head uniformity (rating of 4), closely followed with high ratings for Umpqua, Bay Meadows, and Green Magic (ratings of 3.5). 2014 and 2015 combined results confirm Packman and Umpqua to have consistently good head uniformity and smoothness (Figure 13).

From notes and observations, 2015 baby trial growers noted Umpqua to have cateye, bracting (leaf in head), and brown bead; one trial grower reported Umpqua to have the poorest quality. Green Magic, Bay Meadows, and Packman were also reported to have cateye flaws. Gypsy was found to be the hardest hit by disease at two locations in 2015. Packman was thought to have the best overall quality at two locations. 2014 observations reported cateye, yellowing, and other head discolorations for Umpqua, Green Magic, and Packman varieties, suggesting heat intolerance relative to the other varieties. Bay Meadows and Gypsy were not noted to have any of these flaws in 2014.

Packman, Umpqua, Green Magic, and Bay Meadows are clear choices for heat resistance based on good ratings for uniform bead, head uniformity, and yield.

Additional Quality Traits. Assessing the quality of crown cut heads includes considering the traits related to heat stress performance as well as dome shape, head color, bead size and firmness, and overall quality ratings. These traits were also evaluated on a scale of 1-5 (5 is best).

Dome shape is an important characteristic for quality and marketing. A domed head allows moisture to drip off the crown. All varieties had good dome shape in 2015 baby trials (rating of 3 or higher), Green Magic and Gypsy had excellent dome shape (Figure 14). Belstar and Green Magic had the best dome shaped heads in 2014 baby trials, followed by Bay Meadows, Gypsy, and Packman. All varieties had good, marketable dome shape at all baby trial locations and years.

Head color is important for marketing considerations. A blue green or dark green head is optimal (rating of 5 or 4, respectively), whereas discolorations such as lime green or yellowing are poor (rating of 1 or 2). Packman and Belstar had marketable head color in 2015 baby trials (Figure 15). Umpqua and Packman had the best head color in 2014 baby trials (rating of 4), followed by Bay Meadows and Green Magic (3.5), and Gypsy with a marketable 'green' head color rating of 3. Combined 2014 and 2015 raw data suggests Green Magic, Packman, Gypsy, and Belstar to have optimal head color of green to dark green on average (Figure 16). Packman, Belstar and Umpqua are good choices for head color.

Small bead size and the firmness of broccoli heads give indication of quality at harvest as well as insight to how well the crop will store. 2015 baby trial results show Belstar and Umpqua to have the smallest bead size (average rating of 4), followed by Bay Meadows, then Packman. All varieties had good bead size in 2015 (Figure 17). Combined data from 2014 and 2015 show Umpqua, Belstar and Bay Meadows had the smallest bead over five locations and two years

(Figure 18). Head firmness looks at how compact the beads are; Belstar, Packman, and Green Magic had the tightest heads in 2015 baby trials (Figure 19). Combined 2014 and 20115 data show that only Umpqua and Packman had consistently firm heads with ratings of 3 or higher (Figure 20).

Overall quality refers to the broccoli head quality of an entire plot at time of harvest. Packman, had the highest overall quality rating in 2015, followed by Green Magic, Umpqua, and Belstar (Figure 21). Bay Meadows had the highest overall quality in 2014 baby trials (average rating of 4.5), followed by Green Magic with very good quality (rating of 4). Combined 2014 and 2015 baby trial results highlight Green Magic as the highest average overall quality (rating of 3.5), followed by Packman, and Bay Meadows (Figure 22).

Overall plant vigor of each variety was measured throughout the season. Weak vigor reveals poor performance, while extra vigorous plants often reveal too much vegetative growth and poor heading; an optimal vigor rating is normal (rating of 2). 2015 baby trial averages showed that Packman, Gypsy, and Bay Meadows to have the most normal vigor (Figure 23). Data from the research station 2014 baby trial site showed Bay Meadows and Packman had the most normal vigor rating throughout the season. 2014 and 2015 combined data show Packman and Green Magic had consistently normal vigor (Figure 24).

Insects and Disease: 2015 flea beetle pressure was significant from early summer season forward, similar to 2014 baby trial observations. Gypsy, Bay Meadows, and Packman were least susceptible to flea beetle damage at all 2015 locations (Figure 27). Research station trial site data suggested Bay Meadows to be the most resistant to flea beetles in the 2014 season, consistent with 2013 mother trial results. Combined 2014 and 2015 results showed most varieties had similar susceptibility to flea beetles (Figure 28).

Harlequin bugs are noted by western North Carolina organic growers as the most pressing insect problem, with unknown successful management. Harlequin bugs were persistent and caused significant damage to crop at three 2015 baby trial sites. Harlequin bugs were high pressure beginning mid-season through harvest. Statistical significance of insect resistance was not inferred from 2015 data. Gypsy, Packman, Bay Meadows, and Green Magic were observed to be least susceptible to harlequin bugs at four 2015 locations (Figure 29). Umpqua was the most susceptible to harlequin bugs over all locations and both years of baby trials (Figure 30).

Imported cabbage worms presented low, manageable pressure for baby trials in 2015, consistent with the 2014 results. Farmscaping in addition to Bt products provided good management of worms and larvae. (Data not shown).

In addition to farmscaping and trap crop plantings, effective products for flea beetles and Harlequin bugs included OMRI approved products used at baby trial sites for pest management. Growers began insect spray management as early as June 23rd, 2015 with Bt products such as Dipel, and added Pyganic, and Diatomaceous Earth (Site 3) for control rotations throughout the season. Bt, spinosad, Serenade (*Bt subtilis*), copper products, and neem treatments were applied at observational trial Site 5 with some success for insect and disease management. Spinosad was found to be useful at three locations for flea beetle and harlequin bug management. Bt and Pyganic useful at two locations. One location did not spray.

Alternaria was first noted at site 2 on July 9th, 2015, slow spreading through the next week. The disease caused defoliation and unmarketable heads for two varieties at this non-spray location. Disease was present at first harvest and leaves removed in early August at Site 1, and remained manageable through harvest of most varieties. The Plant Disease and Insect Clinic at NCSU confirmed Alternaria Leaf Spot (*Alternaria sp. /spp.*) from disease samples of two locations in August and September 2015. Participating baby trial growers listed Alternaria and black rot as the most pressing disease issue for summer broccoli on their farms.

Data from 2015 baby trials suggest Bay Meadows to be the most resistant to Alternaria, consistent with 2014 baby trials, followed by Packman, Gypsy and Belstar (Figure 25). Frequent applications of copper products such as Nordox as well as Serenade (*Bt subtilis)* were effective to keep disease from spreading. Copper and copper sulfate were useful at three sites in 2015 baby trials. Spinosad was found to be somewhat effective at two sites, and more so when sprayed in combination or rotation with copper products and fish emulsion – a good option for a spray regime for organic baby trial locations for insect and disease pressure. Double Nickel was somewhat effective for Alternaria and black rot at one site in 2014, and used late in the season in attempts to control disease.

Bay Meadows, Gypsy, and Packman are clear choices for insect and disease resistant varieties.

Participatory Planning and Adoption of Varieties by Local Growers.
Participatory research has gained momentum since the start of our Participatory Organic Broccoli Research Projects in 2012. We have partnered with and been approached by others interested in participatory research in the region due to the success of this project.

We are now collaborating with Cornell University on an organic tomato breeding project and the Organic Seed Alliance on an organic cucurbit breeding project, both of which maintain participatory components. At the start of this project, no such project that we are aware of existed in the South. New participatory organic vegetable research projects will begin in 2016 in partnership with Organic Seed Alliance; research formerly found only on the west coast and Midwest.

Farmers are more likely to adopt practices and varieties that they see their peers successfully using rather than what they read about or see in a research plot. Inviting growers to our research station trials and having them participate in the rating process connects growers and researchers on a peer to peer level. A large majority of growers surveyed said they felt a direct connection to the project and the results. A dozen growers at our end of season 2014 events maintained they would try new varieties and discontinue others based on the results of their hands on, participatory evaluations.

Despite the great performance of the variety Packman in our trials, it is being phased out as the former industry standard. It was difficult to even find seed for it in 2015. Growers and extension agents mentioned how pleased they were to know there were suitable alternative options. Green Magic and Bay Meadows will continue to be grown by our baby trial growers and three new broccoli growers. An organic farm in Swain County will expand to 10 acres of organic broccoli production because of this project. Other growers and Cooperative Extension agents from across

the state contact our program weekly with questions regarding broccoli production, season extension, and appropriate varieties. Umpqua has been a strong performer and stands out to many growers who prefer an open pollinated choice in variety.

Interest continues to grow for summer production of organic broccoli in western North Carolina. We intend to continue providing support on varieties and organic systems management for broccoli in the region.

Systems Approach to Organic Research. Our research with organic broccoli began in 2011, and the successful cultural practices we demonstrated and tested have been adopted more and more since. The use of raised beds with drip irrigation and white plastic mulch was brand new for broccoli production in western North Carolina, and has since been adapted for use for other annual vegetables grown in our region, both organically and conventionally. Farmscaping and trap cropping with groups of plants specific to brassica production are other aspects of a systems approach to organic research we have encouraged.

Early research in the complementary Eastern Broccoli project involved a study on plant population done in New York. Closer in-row spacing than was commonly used was found to generate optimal crown size and higher yields per acre. In-row spacing of 8 inches and 12 to 15 inches between rows (two or three row beds) produce average yields of 600 to 800 boxes per acre. We passed this information on to our organic growers as well, with the additional information that updated spacing research has also been linked to more efficient fertilizer usage.

Mapping is one of the main tools to look at the whole picture of an organic production system. Where crops are and will be, how best to incorporate additional annual and perennial species, drainage plans, and water use are components of mapping that contribute to a way of thinking for the overall system.

In 2015, about 20 new organic farmers in Henderson, Haywood, Yancey, and Buncombe counties (NC), and many more over the previous four growing seasons of this project, have adopted components of the practices we have recommended. All of our on-farm trial growers have received training on a full approach to organic systems research in 2014 and 2015. Nine additional growers have expressed interest in learning more about a systems approach to growing broccoli and for their farms.

Additional Varieties for Organic Farms in Western North Carolina. This project began as an organic component to the Cornell led five state public-private conventional broccoli project. Our goal was to use variety trials as a means to assess the summer production potential of existing varieties for organic growers. The Eastern Broccoli project had a large breeding component from public and private collaborative breeding programs. Many of the new hybrids released from the project are suitable for organic production, and two have been earmarked as ideal for our region's summer organic broccoli production. We intend to share this information as it becomes available.

The Eastern Broccoli Project was funded by the United States Department of Agriculture under the Specialty Crops Research Initiative, with matching contributions from participating

commercial partners**.** The Eastern Broccoli Project goals were to create a regional supply of broccoli, lower transportation costs for broccoli, develop a larger market for the high-value specialty crop for Eastern farmers; develop new breeding stocks and varieties, and create a team of experts to develop an Eastern broccoli industry with an annual value worth $100 million. The research team of breeders, production specialists, and market developers recently concluded five years of field and market research.

To date, the project has created and evaluated 136 new hybrids; of which 46 advanced to phase II trials, and 4 advanced to phase III on-farm trials in western North Carolina (Henderson County). Regional varieties best suited to mountain production were also identified, even two for organic growers with different quality traits. Varieties released or remarketed to the East Coast by the project include: Lieutenant (Seminis), BC1691 (Seminis, a Lieutenant follow-up), BC1764 (Seminis, a Lieutenant follow-up), Burney (Bejo), and Durapak16 and Durapak19 (Syngenta). Additional varieties are scheduled to be available to the public soon, keep an eye out for 'Greenpak' from Syngenta and others from Seminis and Bejo.

For other seasons and additional varieties for the Southeast, see the Broccoli Varieties for the Eastern U.S. from the Eastern Broccoli Project (http://www.hort.cornell.edu/bjorkman/lab/broccoli/evarietyrecs.php); And the 2016 Southeastern U.S. Vegetable Crop Handbook for additional variety recommendations (http://www.thepacker.com/grower/southeastern-us-vegetable-crop-handbook?ss=the_grower).

6. Conclusion

Our 2015 participatory organic broccoli project built on the project we started in 2012 with three grants from the Organic Farming Research Foundation. In 2012 and 2013, farmers helped develop and evaluate the Phase I mother trials containing 20 crown cut broccoli varieties. In 2014 and 2015 we conducted Phase II baby trials on certified organic land on a research station and on organic farms in western North Carolina to further evaluate the six top performing varieties identified in the 2012-2013 mother trials.

The project is participatory in nature and execution. Growers, industry, and NC Cooperative Extension agents were involved in project planning, implementation, and evaluation. Facilitating a whole systems approach for organic research projects was also focused on.

For organic summer broccoli production in western North Carolina, the best performing crown cut varieties identified from this project for yield, quality, and disease and insect resistance/tolerance are Bay Meadows, Packman, Green Magic, and Umpqua. Additional varieties bred through the complimentary Eastern Broccoli Project for heat resistance are flagged as appropriate for WNC organic broccoli growers as well.

A field day and on farm harvest workshops brought western North Carolina organic broccoli stakeholders together to evaluate the varieties in the 2015 baby trials on the research station and on-farm trial locations. A winter broccoli meeting and presentation from researchers and experienced broccoli growers contributed to the results of the baby trials and where to go from here for the North Carolina mountain broccoli industry.

7. Outreach Activities

A winter vegetable school in Hendersonville, NC on February 5th, 2015 included a presentation by Margaret Bloomquist on organic and conventional broccoli as an emerging crop in western NC.

We had an exhibit on the project at the 2015 Winter Vegetable Conference in Asheville, NC on February 25th. There were over 200 people in attendance.

The annual Tomato Field Day at the Mountain Horticultural Crops Research and Extension Center on August 13th, 2015 showcased our broccoli research through a project poster and presentation. There were over 150 in attendance.

We had a broccoli grower meeting on December 2, 2015 in Mills River, NC to educate local organic and conventional farmers about the opportunities for local broccoli production.

Bejo Seeds planted a trial of over 100 new lines from their Dutch breeder at the Mountain Research Station in Waynesville, NC. This is a good opportunity to have the breeders out to our organic trials more and learn about their first line of variety trialing.

North Carolina Extension agents had a broccoli trial at the Piedmont Research Station. We have been consulting and providing resources to the Extension team and look forward to more collaborations.

8. Leveraged resources

As reported in our 2014 final report, our involvement with the project was integral in creating a relationship with the Organic Seed Alliance. We began field trials as part of the multi-state Organic Cucurbit Breeding Project with them in 2014, led by Cornell and funded by OREI. We have collaborated on a number of project proposals and intend to continue participatory organic research with their partnership. There are currently four pending federal grant proposals that directly or indirectly developed as a result of this project.

Another important partnership that has grown considerably due to this project is our relationship with Carolina Farm Stewardship Association. We collaborated on hosting field days for the past four years, and in 2014 they expanded organic broccoli variety trials to other regions of North Carolina as part of a Specialty Crops Block Grant and SCRI funding. We work closely with one another for maximum affect and share variety info and field management considerations.

Acknowledgments

We thank the 2015 baby trial hosts for their input to the project and collaborations throughout the growing season, specifically Jon Miller of Miller Farms, Richard and Christina Moyer of Moyer Family Farm, Rachel Meriwether of Green River Preserve Farm, and Wallace Souther of Hooper's Creek Botanicals. We appreciate the contributions of the crew at the Mountain Research Station and North Carolina Department of Agriculture and Consumer Services in making this project happen, especially the efforts of Kaleb Rathbone and Kyle Miller. We also

appreciate the guidance from Dr. Thomas Bjorkman at Cornell University, Richard Boylan and Craig Mauney of the North Carolina Cooperative Extension Service, Micaela Colley and Tony Kleese of Organic Seed Alliance, Michael Mazourek of Cornell, and Karen McSwain of Carolina Farm Stewardship Association.

Note: The use of brand names and any mention or listing of commercial products or services does not imply endorsement by North Carolina State University nor discrimination against similar products or services not mentioned.

Appendix I: Figures

Figure 1: 2015 Locations and Elevations of Baby Trials

Replication	Location	Elevation (feet)	Seeding Date	Transplant Date
1	Waynesville, NC	2,700	5/13/15	6/18/15
2	Zirconia, NC	2,300	5/13/15	6/15/15
3	Marble, NC	1,680	5/13/15	6/16/15
4	Castlewood, VA	1,800	5/15/15	6/24/15
5	Fletcher, NC	2,100	5/13/15	6/22/15

Figure 2: 2015 Organic Broccoli Varieties

Variety	Type	Seed Source
Umpqua	OP	Southern Exposure Seed Exchange
Belstar	Hybrid	Johnny's Selected Seeds
Bay Meadows	Hybrid	Fedco
Green Magic	Hybrid	Johnny's Selected Seeds
Gypsy	Hybrid	Johnny's Selected Seeds
Packman	Hybrid	Jung Seeds

Figure 3: 2015 Organic Broccoli Plot Layout

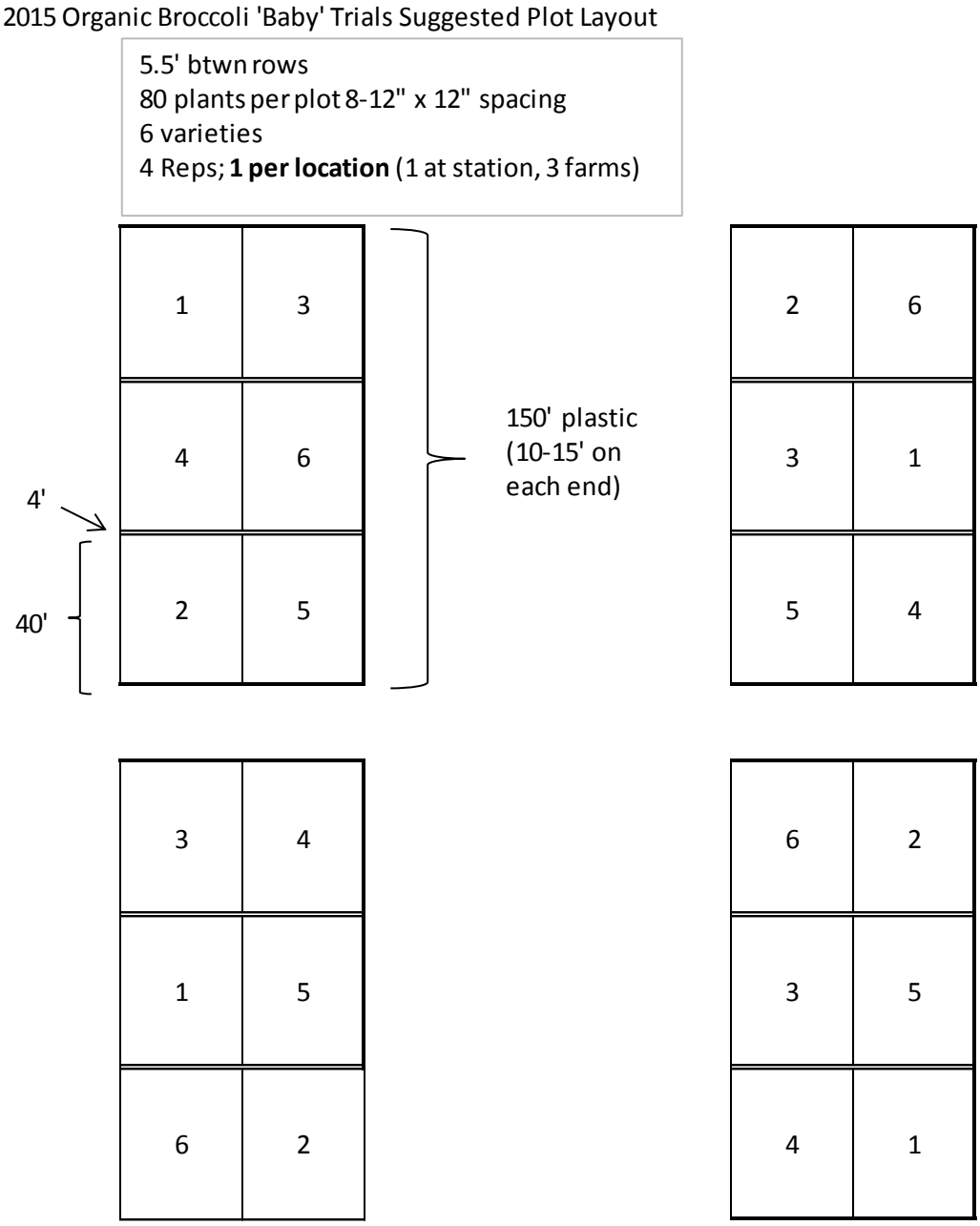


Figure 4: 2011-2015 Seasonal Rainfall. CRONOS Weather Data from Mountain Research Station, Waynesville, NC.

Rainfall Inches/Month	April	May	June	July	August	September	Total Rainfall
2011	5.44	2.22	5.24	3.56	1.07	3.67	21.2
2012	4.97	3.41	1.03	7.52	2.26	3.75	22.94
2013	6.55	4.68	5.81	12.99	3.17	3.54	36.74
2014	6.11	3.63	3.55	3.9	2.29	2.14	21.62
2015	**8.8**	**4.1**	**3.55**	**7.01**	**2.59**	**5.57**	**31.62**

Figure 5: 2012-2015 Maximum Heat Index (F). CRONOS Weather Data from Mountain Research Station, Waynesville, NC.

Heat Index (Max. F)	April	May	June	July	August	September
2012	81.1	82.2	97.3	94.1	87.1	86.3
2013	79.7	80.9	85.7	87.3	86	84
2014	77.6	82.7	87.4	87.6	86.3	86.4
2015	**78.8**	**81**	**90.7**	**88.4**	**87.4**	**85.1**

Figure 6: 2015 Farmscaping and Trap Cropping Field Layout. Certified Organic Research Unit, Waynesville, NC.

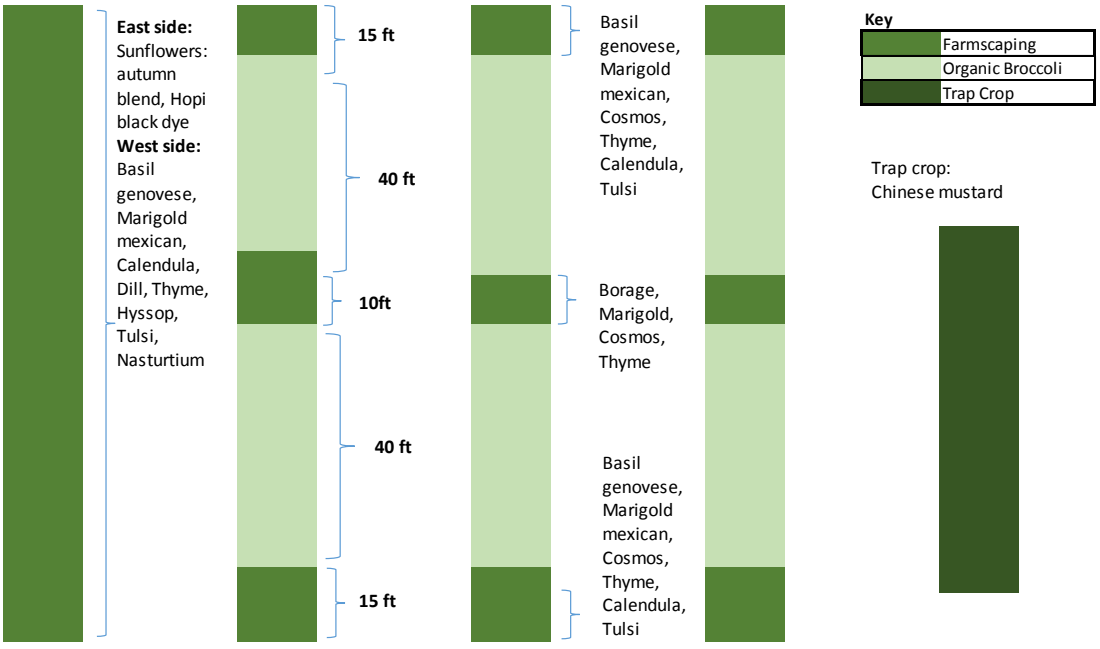


Figure 7: 2015 Total Yield of Organic Broccoli Varieties, All Locations

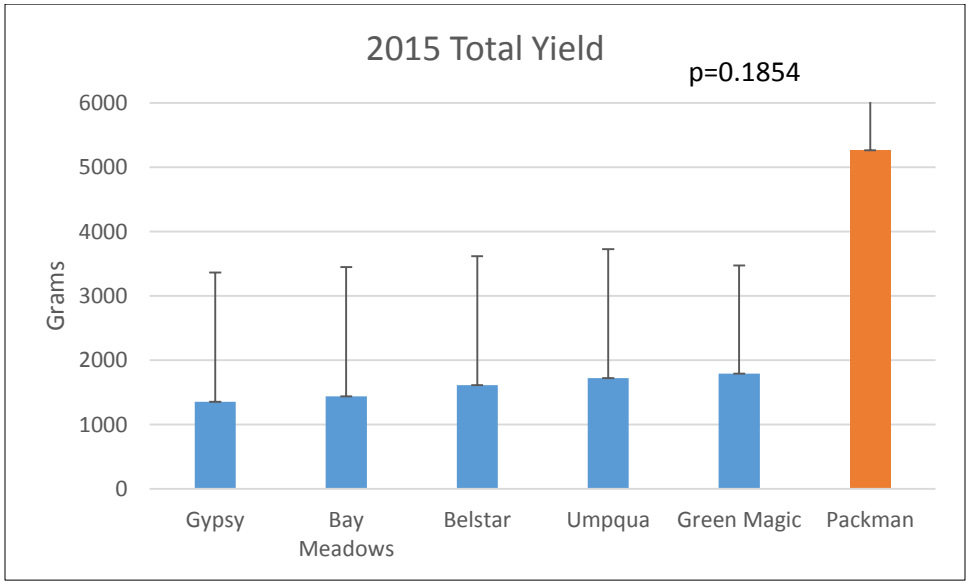


Figure 8: 2014 and 2015 Combined Total Yield of Organic Broccoli Varieties, Site 1 Raw Data

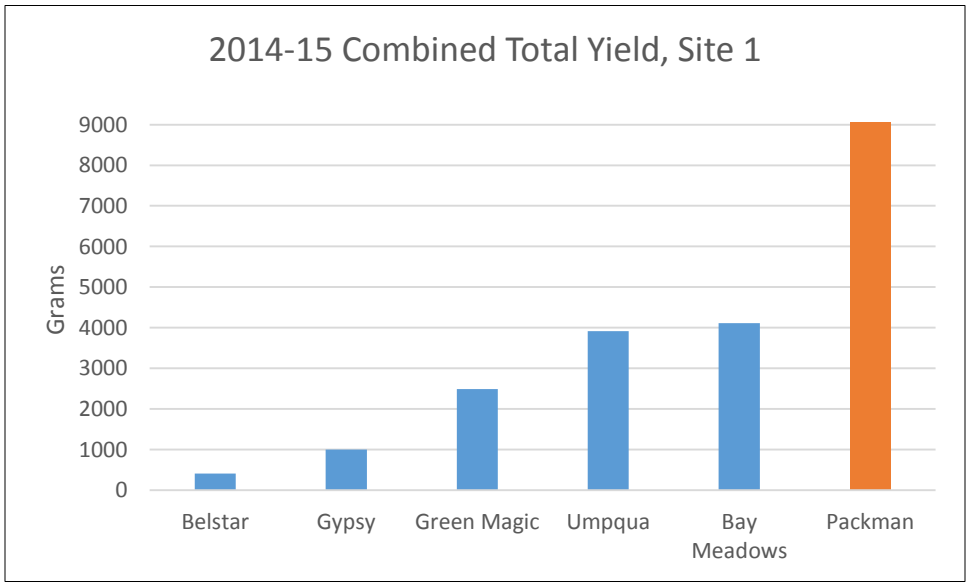


Figure 9: 2014 and 2015 Total Adjusted Yields of Organic Broccoli Varieties, Site 1 Raw Data

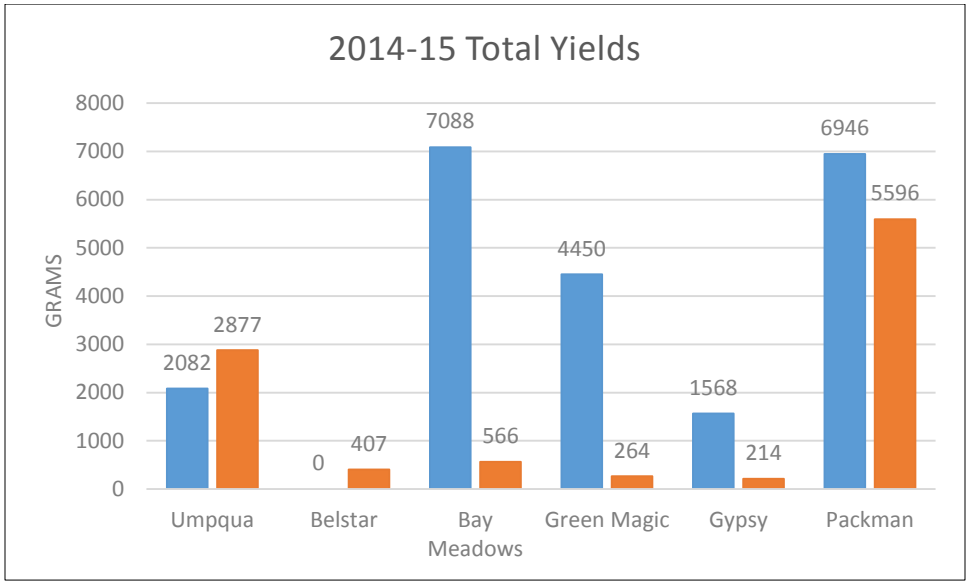


Figure 10: 2015 Average Uniform Bead of Organic Broccoli Varieties, 2 Locations

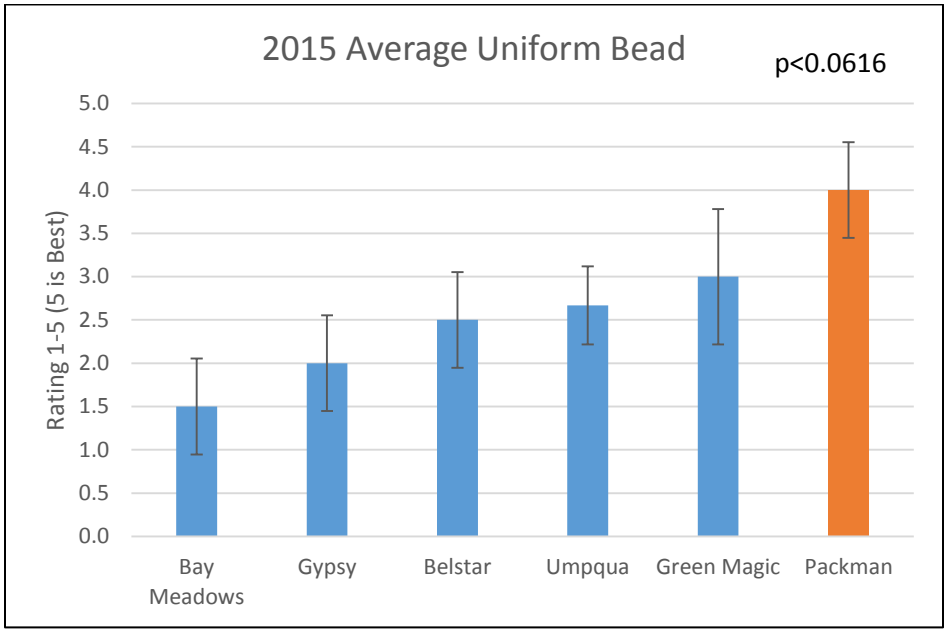


Figure 11: 2014-15 Combined Average Uniform Bead of Organic Broccoli Varieties, 5 Locations, Raw Data

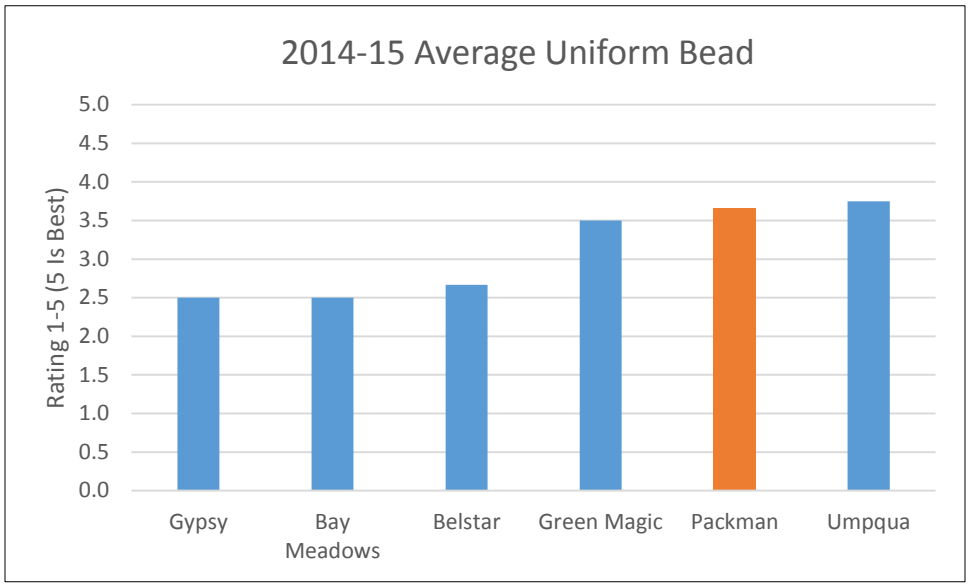


Figure 12: 2015 Average Head Uniformity/Smoothness of Organic Broccoli Varieties, X Locations, Raw Data

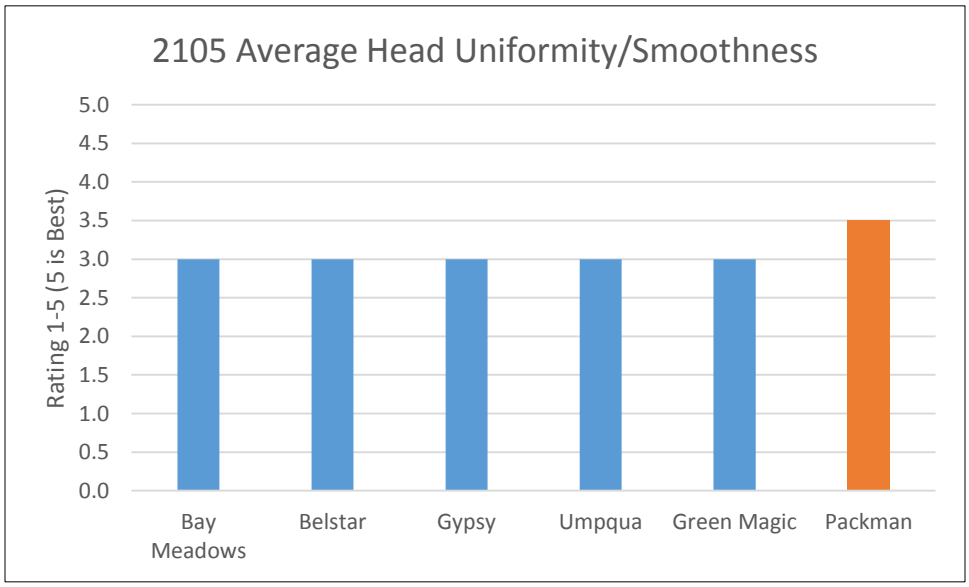


Figure 13: 2014-15 Combined Average Head Uniformity/Smoothness of Organic Broccoli Varieties, 3 Locations, Raw Data

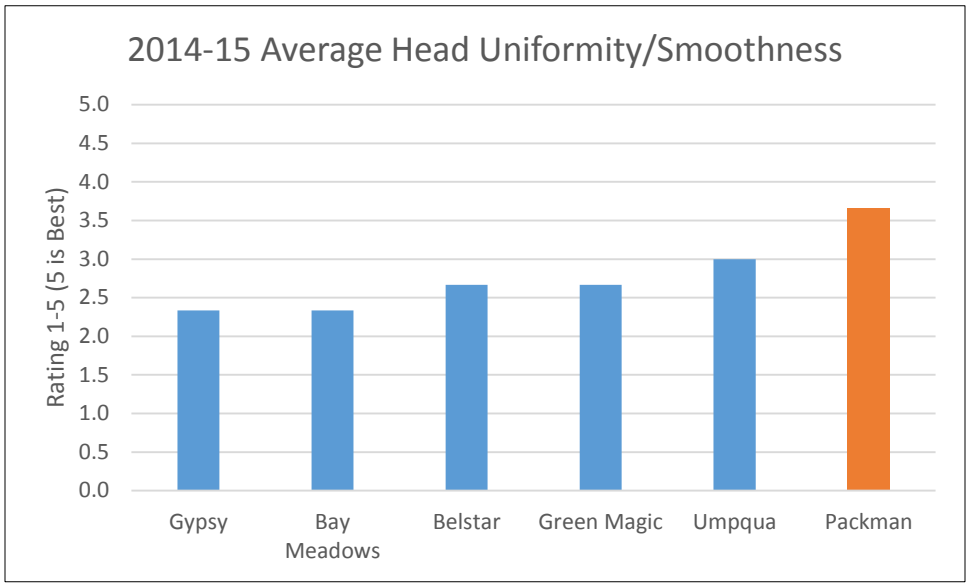


Figure 14: 2015 Dome of Organic Broccoli Varieties, 2 Locations, Raw Data

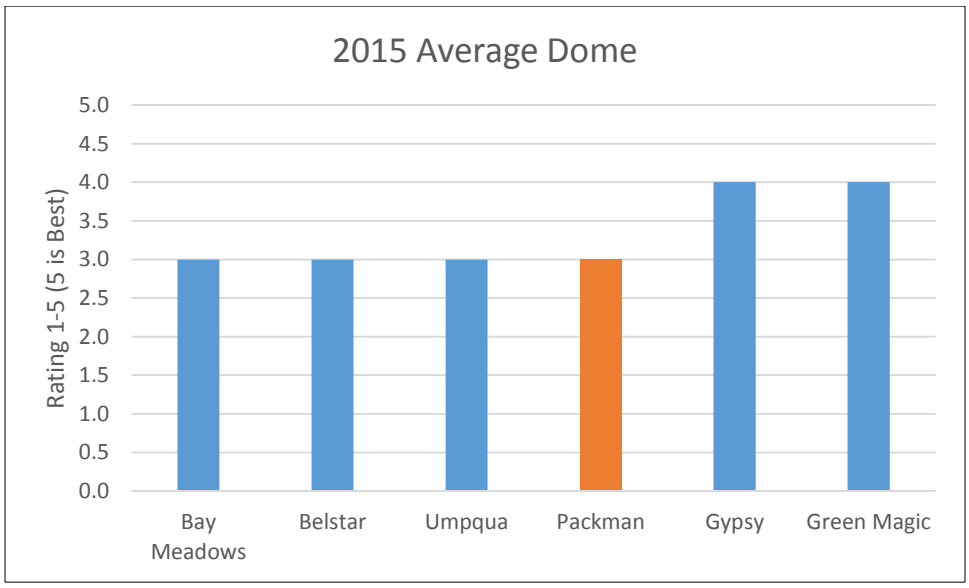


Figure 15: 2015 Average Head Color of Organic Broccoli Varieties, 3 Locations

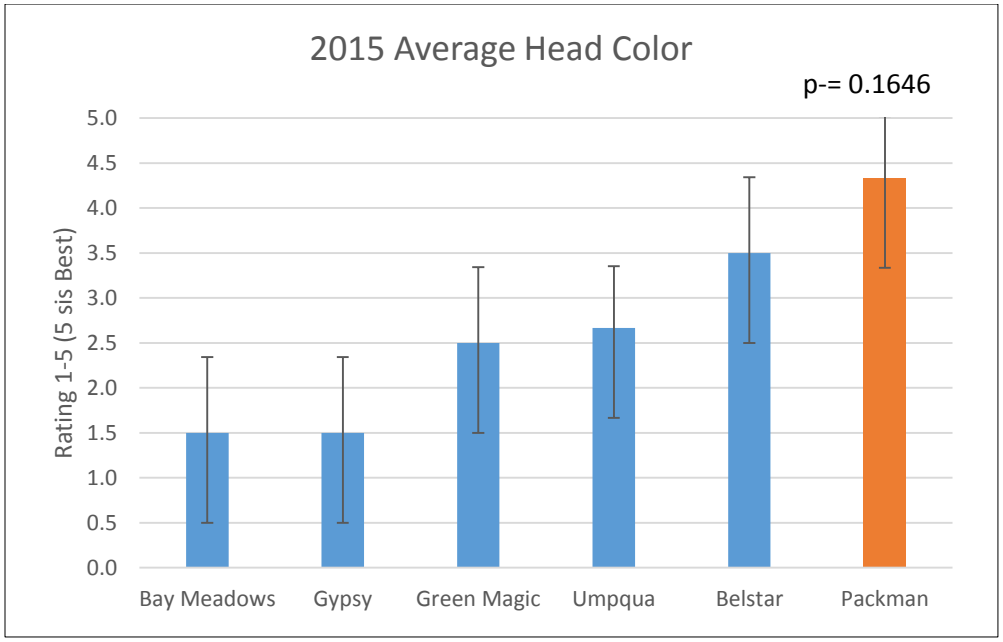


Figure 16: 2014-15 Combined Average Head Color of Organic Broccoli Varieties, 2 Locations, Raw Data

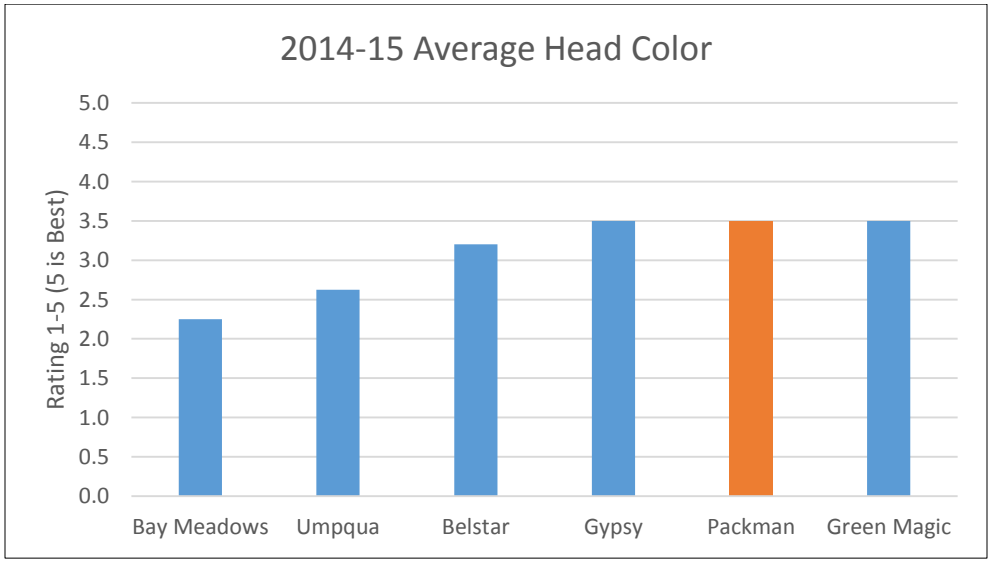


Figure 17: 2015 Average Bead Size of Organic Broccoli Varieties, 3 Locations, Raw Data

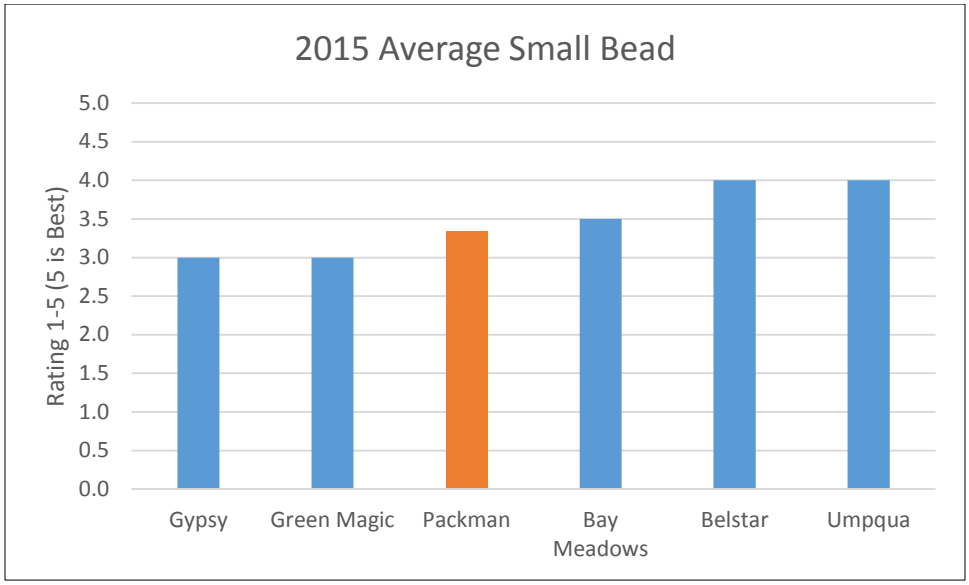


Figure 18: 2014-15 Combined Average Small Bead Size of Organic Broccoli Varieties, 5 Locations, Raw Data

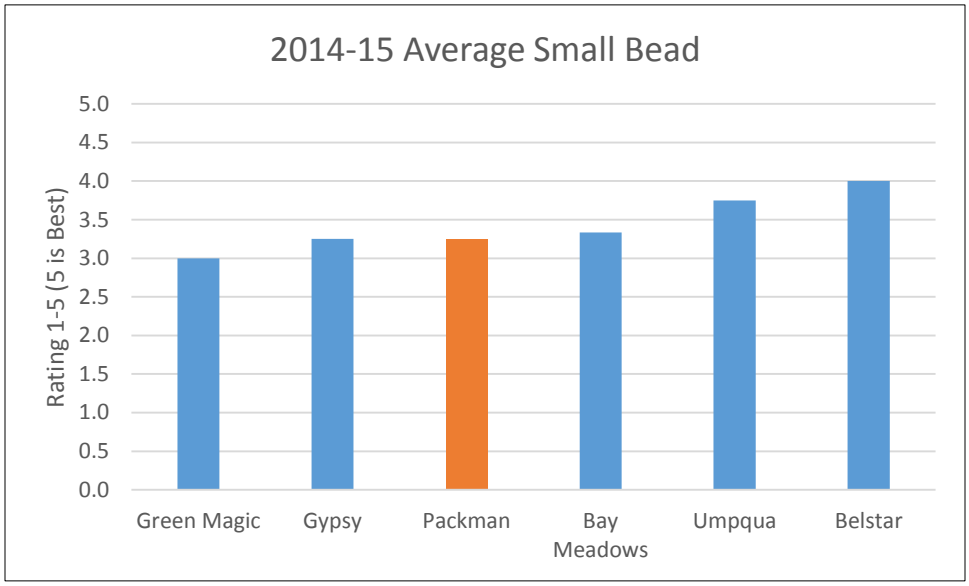


Figure 19: 2015 Average Firmness of Organic Broccoli Varieties, 3 Locations

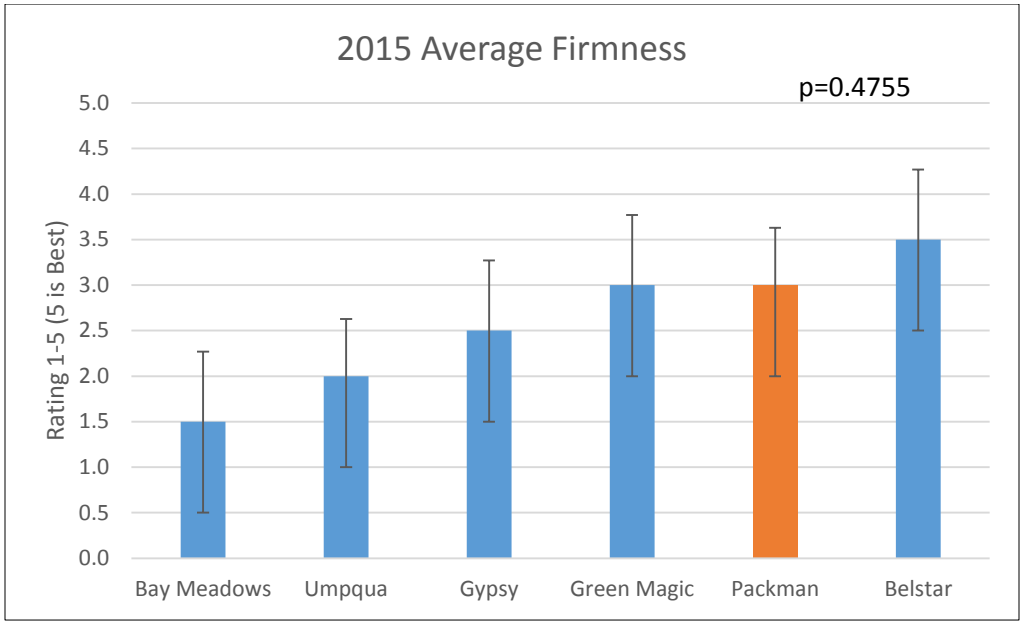


Figure 20: 2014-15 Combined Average Firmness of Organic Broccoli Varieties, 5 Locations, Raw Data

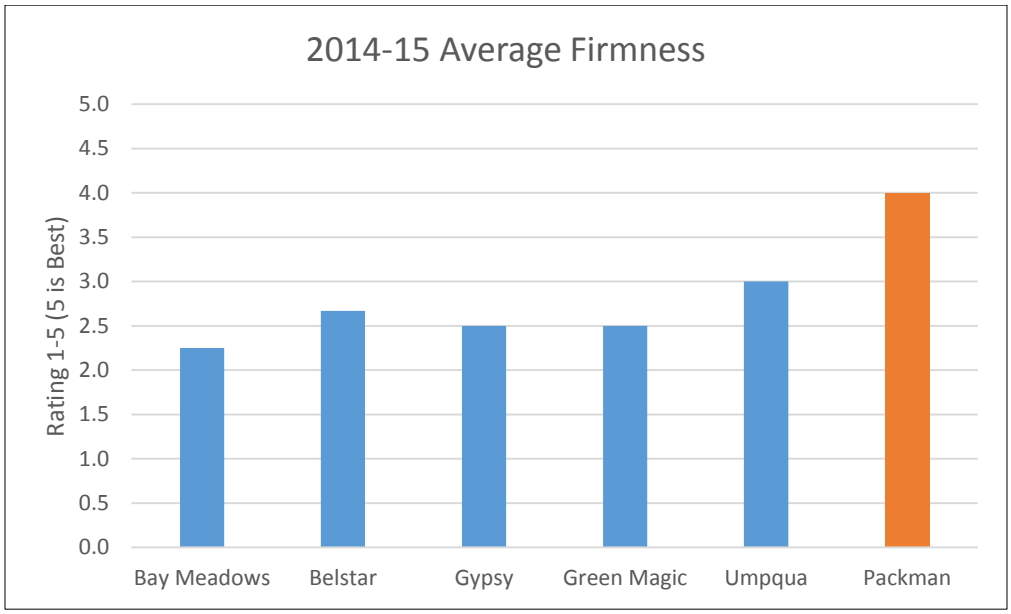


Figure 21: 2015 Average Overall Quality of Organic Broccoli Varieties, 3 Locations

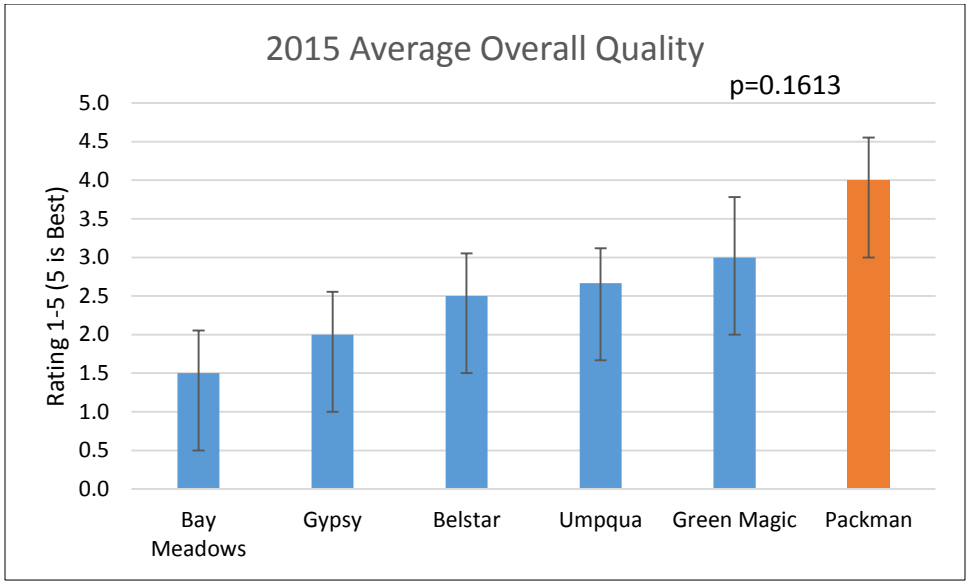


Figure 22: 2014-15 Combined Average Overall Quality of Organic Broccoli Varieties, 5 Locations, Raw Data

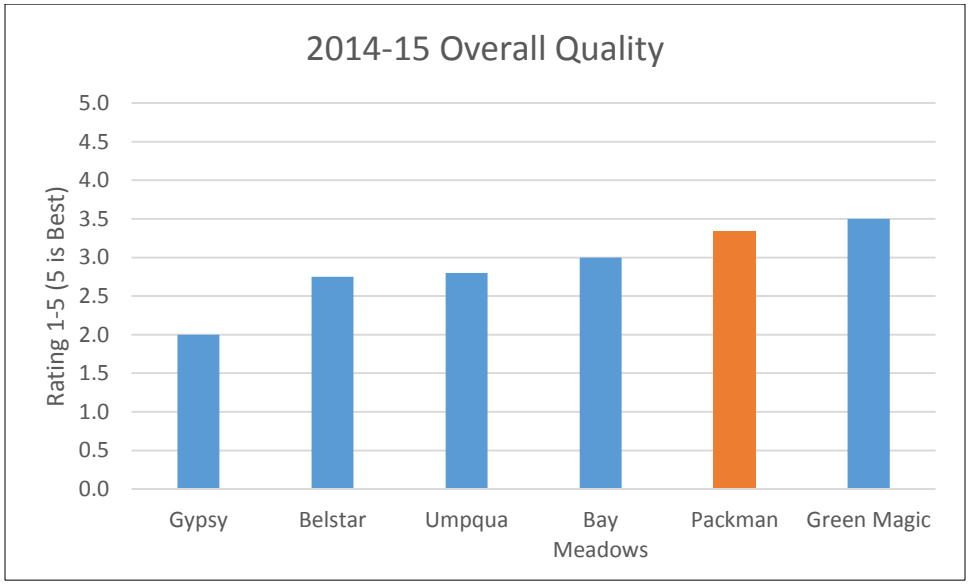


Figure 23: 2015 Average Plant Vigor of Organic Broccoli Varieties, 5 Locations, Raw Data

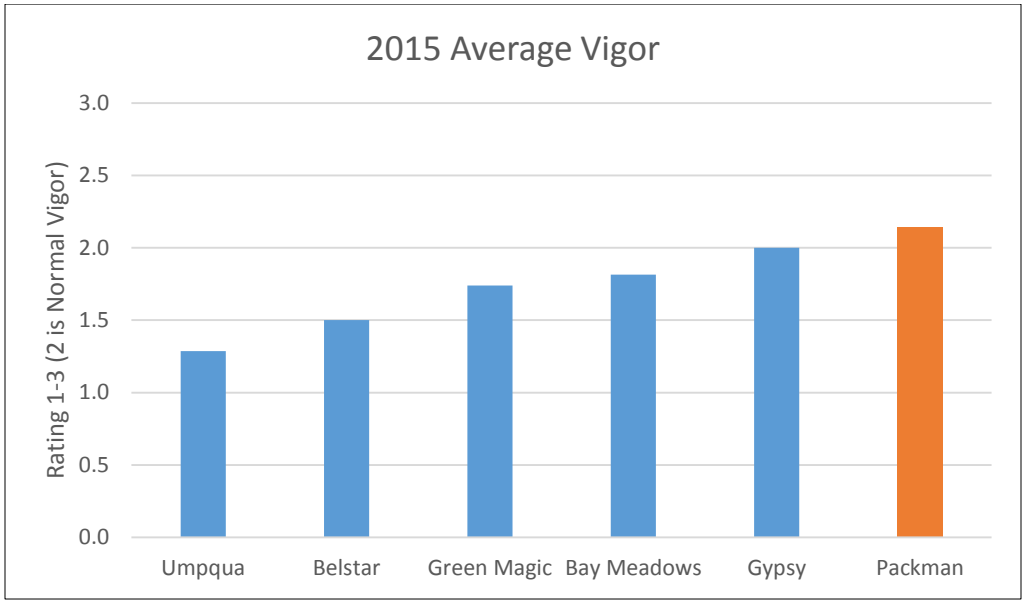


Figure 24: 2014-15 Combined Average Plant Vigor of Organic Broccoli Varieties, 5 Locations, Raw Data

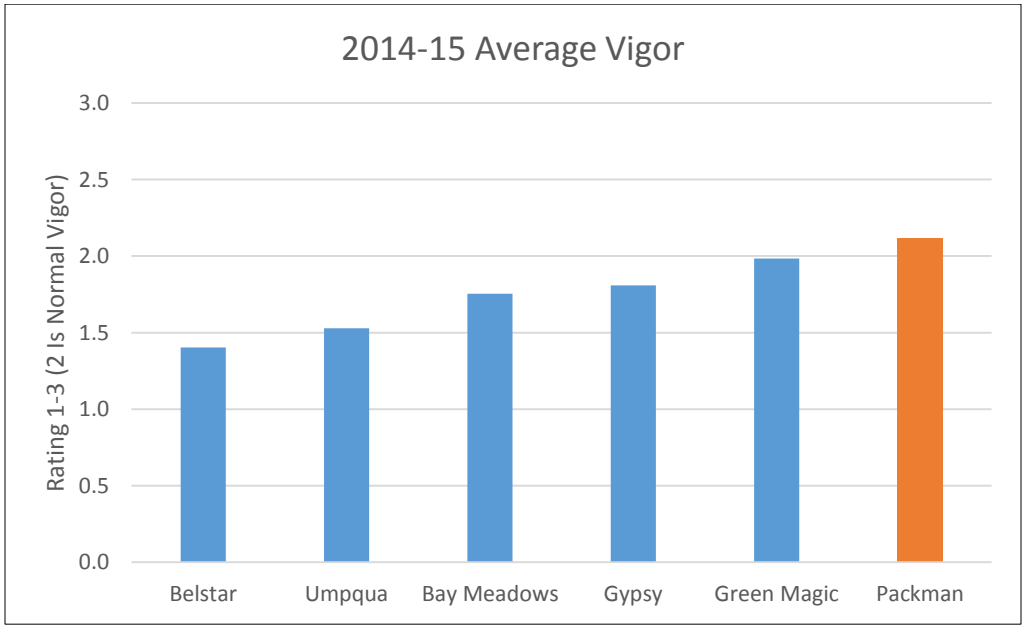


Figure 25: 2015 Average Alternaria Susceptibility of Organic Broccoli Varieties, 5 Locations

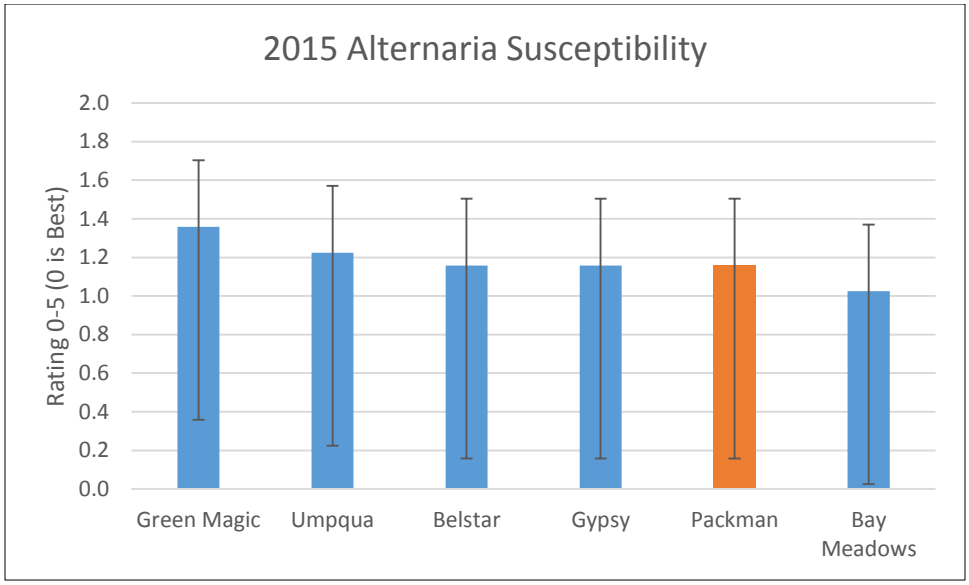


Figure 26: 2014-15 Combined Average Alternaria Susceptibility of Organic Broccoli Varieties, 5 Locations

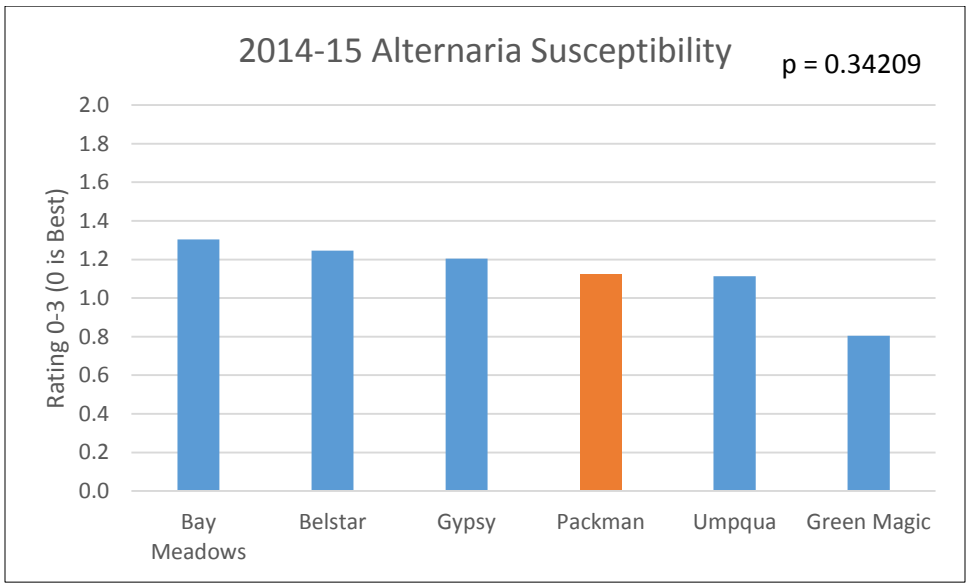


Figure 27: 2015 Average Flea Beetle Susceptibility of Organic Broccoli Varieties, 5 Locations

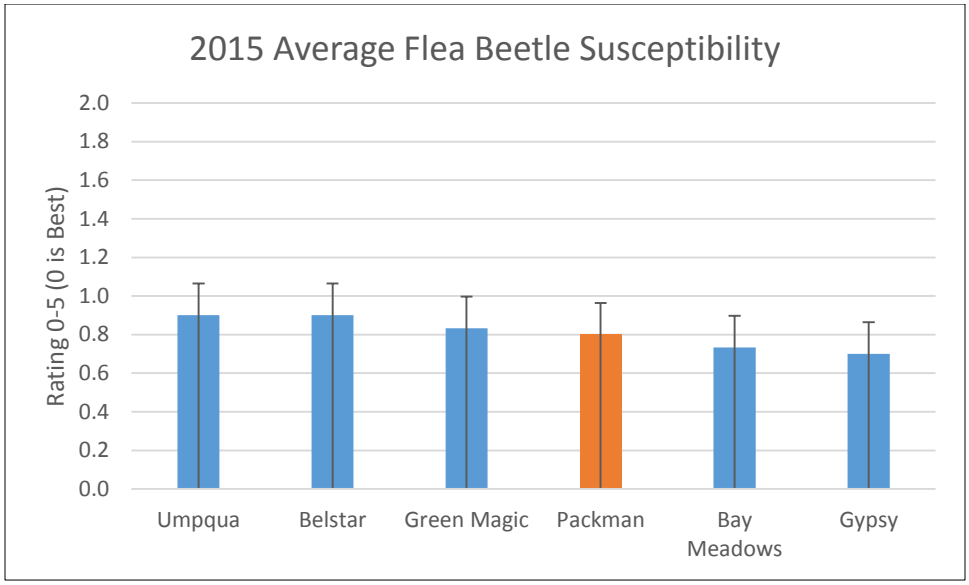


Figure 28: 2014-15 Combined Average Flea Beetle Susceptibility of Organic Broccoli Varieties, 5 Locations

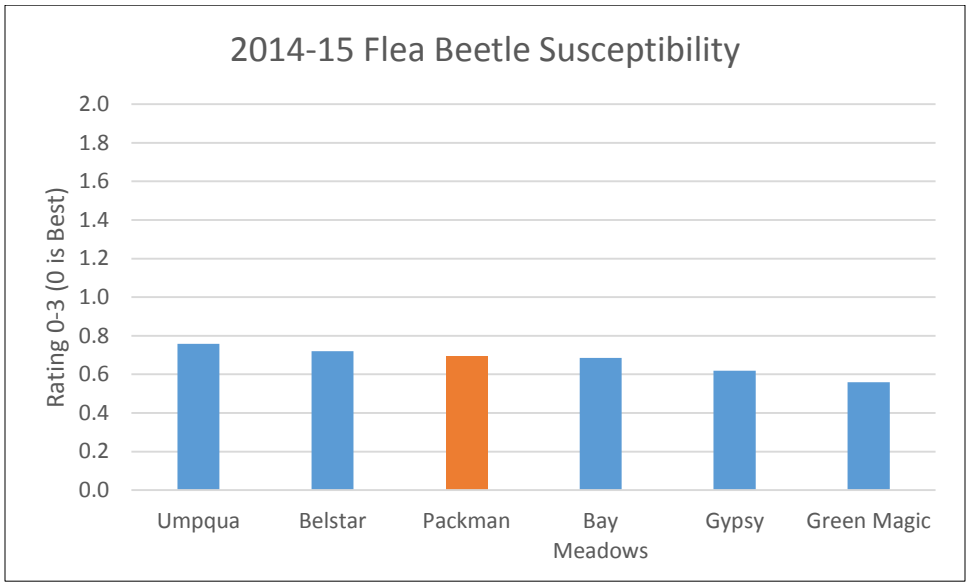


Figure 29: 2015 Average Harlequin Bug Susceptibility of Organic Broccoli Varieties, 5 Locations

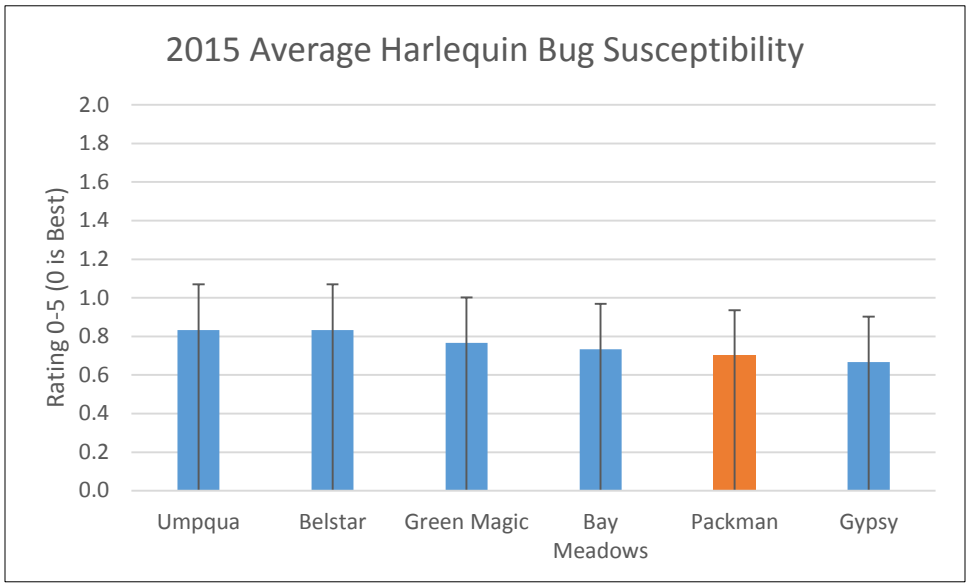
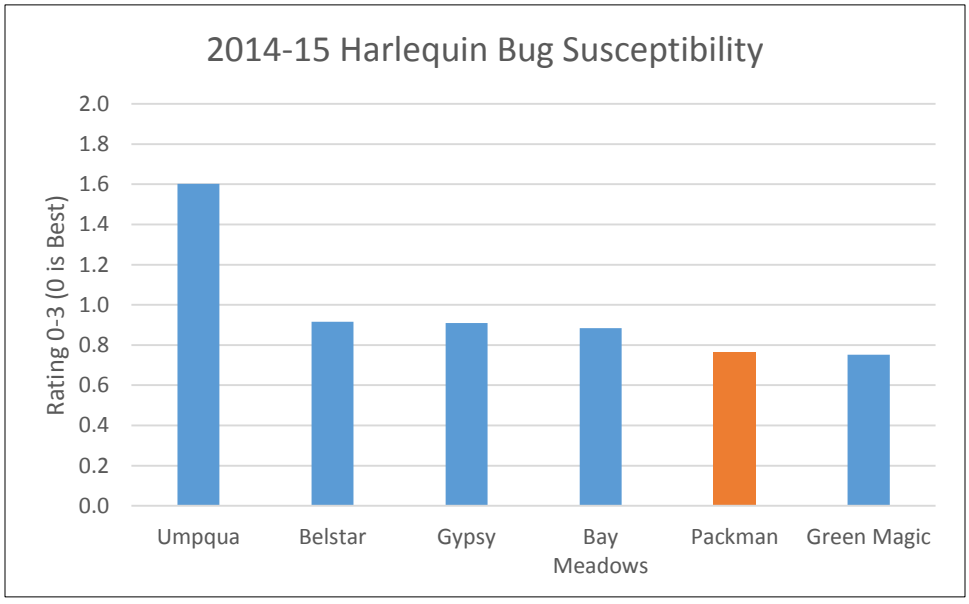


Figure 30: 2014-15 Combined Average Harlequin Bug Susceptibility of Organic Broccoli Varieties, 5 Locations



Appendix II: Images

Image 1: 2015 Seedlings of Organic Broccoli Varieties

Image 2: 2015 Field Preparation for Organic Broccoli Baby Trial, Location 1

Image 3: 2015 Transplant of Organic Broccoli Varieties, Location 1

Image 4: 2015 Transplant of Farmscaping Plants, Location 1

Image 5: 2015 Farmscaping Layout for Organic Broccoli Baby Trial, Location 1

Image 6: 2015 Field Layout at Planting, Location 1

Image 7: 2015 Field Layout at Midseason, Location 1

Image 8: 2015 Trap Crop Germinating, Location 1

Image 9: 2015 Trap Crop Field Layout at Germination, Location 1

Image 10: 2015 Plot Layout, Site 2

Image 11: 2015 Field Layout, Site 2

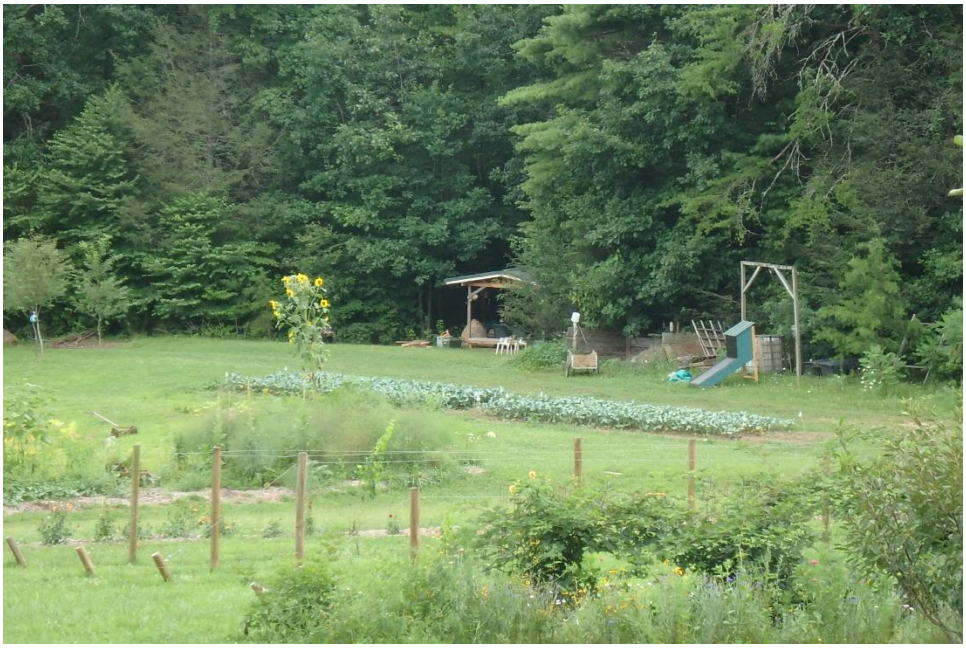


Image 12: 2015 Field Layout, Site 3

Image 13: 2015 Transplant of Organic Broccoli Varieties, Site 4

Image 14: 2015 Insect and Disease Scouting of Organic Broccoli Baby Trial, Site 1

Image 15: 2015 Harlequin Bug Scouting, Site 1

Image 16: 2015 Early Flea Beetle Damage on Chinese Mustard Trap Crop, Site 1

Image 17: 2015 Harvest of Organic Broccoli Varieties, Site 1 Packman Harvest, August 5th, 2015

Image 18: 2015 Data Collection, Site 1 Packman Harvest, August 5th, 2015

Image 19: 2015 Packman Harvest, Site 1 August 5th, 2015

Image 20: 2015 Harvest of Organic Broccoli Varieties, Site 3

Image 21: Children Learning about Broccoli Research at Site 2, July 26th, 2015

Image 22: NC Regional Agronomist Contributing to Broccoli Research, Chris Leek

Image 23: Alternaria on Broccoli Leaf, Site 2, July 21st, 2015

Image 24: Harlequin Bug and Worm Damage, Site 3, 2015

Image 25: Brassica Disease Wipes out Baby Trial, Site 4, 2015

Image 26: ‘Cateye’ Deformation of Organic Broccoli Head

Appendix III: Data Collection Materials

A. Organic Participatory Broccoli Trial 2015 – Harvest Data Sheet_Quality (Fill out one per variety at time of harvest)

Site/Rep _____
Date _____
Notes_____

Variety ___	**RATING**				
DTM:	**1**	**2**	**3**	**4**	**5**
Head Extension					
Plot Uniformity					
Head Color					
Dome					
Head Unif/Smth					
Head Firmness					
Small Bead					
Uniform Bead					
Overall Quality					
Holding Ability (5-7 days later)					
Yield (g) =		Harvestable heads			
Yield (boxes)		Unharvestable plants			
Notes:					

B. Organic Participatory Broccoli Trial 2015 – Harvest Data Sheet_Quantity (Record at any harvest of marketable or unmarketable heads)

Rep/ Site	Variety (1-6)	Date	Market-able heads	Marke-table heads	Unmarket-able heads	Unmarket-able heads	Reason for Unmarket-ability	Comments
			(#)	(g)	(#)	(g)		

C. Organic Participatory Broccoli Trial 2015 - Insect and Disease Data Sheet

Site/Rep _____

Date	Variety	Vigor	Insect Damage	Disease Pressure	Comments/Observations

Key: Variety = # 1 - 6
Vigor - W = weak, N = normal, E = extra vigorous
Insect Damage - Scale 1 - 5, % leaf surface area with **new damage**
1= 0-10%, 2 =10-25%, 3=25-50%, 4=50-75%, 5= >75% OR
0 = none, L = Low, M = moderate, H = High
Disease Pressure 0 = none, L = Low, M = moderate, H = High