

An Evaluation of Eight Basil Cultivars for Downy Mildew Resistance in Virginia

Jason B. Cooper

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Committee

Steven L. Rideout, Virginia Polytechnic Institute and State University

Holly L. Scoggins, Virginia Polytechnic Institute and State University

David B. Langston, Virginia Polytechnic Institute and State University

Abstract

Production of fresh herbs is a trendy market that continues to grow in popularity in the United States. Basil (*Ocimum baasilicum*) is such an herb that is experiencing growth in popularity, especially sweet basil. In Virginia, sweet basil production is increasing and can occur both within the field and greenhouses. However, basil production faces certain challenges, with the most serious one being disease losses caused by downy mildew. With few effective control measures available it is important to find management practices that can assist in controlling this disease, particularly in organic systems. Thus, studies were performed examining eight different sweet basil cultivars during the summer growing season of 2019. The study took place at Adam's Apples and Herbs, located in Shenandoah County in the Shenandoah Valley of Virginia and at Virginia Tech's Eastern Shore Agricultural Research and Extension (ESAREC) in Painter. At harvest, basil was weighed, by leaf and by stem, and then an average of the weight was calculated as was the height of each cultivar. Disease incidence and severity for each basil cultivar was recorded throughout the course of the study. Little disease occurred during the course of the study in the Shenandoah Valley. However, significant differences in basil cultivar growth and appearance were noted. At the ESAREC, downy mildew did develop and resistant cultivars proved to be effective at suppressing disease.

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INTRODUCTION

Basil (*Ocimum basilicum*) production, both in open fields and greenhouses has increased significantly in recent years because of escalating consumer demand and the sale value. Basil production and value statistics are combined with all fresh market herbs, excluding parsley. According to the 2012 and the 2017 US Agriculture Census, the number of Virginia farms that harvested fresh cut herbs grew from 51 to 207 with the number of acres increasing from 29 acres in 2012 to 84 acres in 2017 (USDA-NASS, 2019). Most of the basil produced in the Commonwealth of Virginia is sold fresh for the use as a spice or in flavoring of many culinary dishes. The production of basil in the United States has significantly increased in the past several years because of its high demand as a fresh or dried culinary herb, as a source of essential oil and oleoresin for food flavors, and as an ingredient for manufacturing perfumes, pharmaceuticals and aroma therapeutic products (Mersha et al., 2012). Due to the wide range of uses, basil demand and production is increasing.

Basil can be grown in greenhouse or in covered structures as well as in the field. Growing in greenhouses allows for an extended growing season, especially in northern climates. Growing in the field is more time sensitive due to the weather, as basil grows the best between 45° F and 80° F. Basil plants that are grown in the field are very frost susceptible, thus limiting the growing season length in many parts of the United States.

Not only is there a growing market for commercially grown basil, there is also a huge increase in homeowners growing basil for their own personal needs. The desire to know where your food is grown is of great importance for many consumers, thus making growing your own vegetables and herbs very popular. Basil is an herb that can be grown on a back porch or deck in

a container for easy access. Not only can it be grown in containers, consumers can also grow in raised beds or conventional gardens. Basil works so well in the home environment because it lends itself well to small spaces and has many different uses.

Basil also has a reputation of being an insect repellent, particularly for mosquitos. Despite its insect repellent properties, basil is subject to a variety of pests, including Japanese beetles, grasshoppers, slugs, aphids, spider mites, whiteflies, cutworms and nematodes (Meyers, 2003).

Basil can be directly seeded or transplanted. Most of the direct seeding is done 4-6 weeks before the first frost (Meyers, 2003) in controlled environments. Transplants should be planted safely past the frost occurrence. Most basil plants grown commercially are started from seed and transplanted into the field. For homeowners, most basil is bought as transplants in containers and transplanted to the container or garden.

Basil is also susceptible to many diseases that can be difficult to control due to the lack of products labeled for use on basil and herbs in general. The most common diseases of basil are Fusarium wilt and crown rot, gray mold, black spot, and the most destructive of all downy mildew. An integrated disease management approach that includes cultural practices, careful irrigation, fertility management, soil disinfestation, application of biocontrol agents (when available), and limited fungicide use is necessary to produce high-quality basil (Garibaldi et al., 1997).

Due to the destructive nature of downy mildew, finding resistant cultivars is critical for the herb and basil industry. Thus, trials were performed examining eight different basil cultivars during the 2019 growing season. These studies took place at Adam's Apples and Herbs, located

in Woodstock, Virginia in the Shenandoah Valley and Virginia Tech's Eastern Shore AREC in Painter, VA.

Objectives

The purpose and objectives of this project were to determine if selected cultivars of basil would be resistant to downy mildew and to determine if the selected cultivars would be productive in the Shenandoah Valley and Eastern Shore of Virginia. Eight cultivars that were evaluated during the 2019 growing season. During the growing season, height data was collected, and at the end of the growing season, weight, stem weight, and total plant weight were collected. Throughout the growing season disease was also monitored.

Literature Review

History of Basil

Indigenous to Asia and Africa, basil (*Ocimum* spp.) is part of the *Lamiaceae* mint family. It is grown in regions throughout the world, but primarily in France, Greece, Egypt, and the United States. There are over 60 varieties of this potent herb, each differentiated by its leaf appearance and pungency. Sweet basil (*Ocimum basilicum*) is the one of the most economically important herbal crops in the United States and worldwide. Sweet basil, is used for fragrance, flavor, fresh culinary and dried herb industries (Patel et al., 2016).

Basil is thought to have been brought to ancient Greece by Alexander the Great (356-323 B.C.E), then to have progressed to England from India in the mid-1500s and arrived in the U.S in the early 1600s. Basil was grown in medieval gardens and is mentioned among classic herbals, including those of Culpeper, Gerard, Parkinson and Dioscorides (Meyers, 2003). Basil has been

used in many different capacities throughout history. It has been used in religious traditions, for love and courtship, for protection and luck, medicinal purposes, and as an insect repellent to just name a few (Meyers, 2003). Today basil is primarily used for culinary purposes as a flavor for food and drink and has gained popularity for its ease to grow and flavor.

Basil Production

Basil is primarily grown from seed and transplanted into the field or container. Basil is grown primarily outdoors in field settings, however, basil is produced in greenhouses and indoors as well. Typically, production of basil occurs in raised beds and also utilizing plastic mulch for weed control and moisture management. Growing basil in a greenhouse environment has allowed for an extended season, allowing production in northern climates and during times when outdoor conditions are not favorable.

Basil is a warm season crop that thrives when daytime temperatures are over 70° F and nighttime temperatures remain above 50° F. Starting basil seeds indoors is a common practice. Generally, seeds should be started about 4-6 weeks before the last frost (Meyers, 2003). Most basil will take 8-14 days to germinate under favorable conditions and the seed can be planted rather shallow or even placed on the top of the soil under moist conditions. To encourage lateral branching and growth, the tops of the transplants can be trimmed prior to field planting, when they are about six inches tall (Simon, 1995). This enables the plants to be denser with more foliage which is the marketable part of the plant. Outside plantings should not be conducted until the threat of frost is over.

Outdoor basil plantings require sunshine where the plants receive six to eight hours of full sun daily. A rich, light, well-drained soil with a pH between 6 and 7 is best for basil

production (Shepperson, 2016), but it will also grow in many soils that are both more acidic or alkaline. It is wise to have a soil test done before planting any basil outdoors to know the status of the soil. Basil plants will do best in a consistently moist soil that does not dry out or become saturated. Plants can also be planted in containers using soil medias that have good drainage and contain ample organic matter.

Basil is a water loving plant, requiring about 53 inches of rainfall or water annually but can survive between 23 and 165 inches (Meyers, 2003). Although basil requires water it is also important that the plants are not over irrigated as more basil is lost due to standing in water than not having enough water. An even supply of moisture via overhead or trickle irrigation is necessary (Simon, 1995). Monitoring the moisture in the soil is essential to optimal development and growth of the plant.

Basil plants do not require a large amount of fertilizers to grow. As the season progresses a nitrogen-rich fertilizer can be applied to help make the plants denser and taller to have more marketable leaf material available. Soils that lack the essential nutrients will lack growth and density as basil plants grow. It is important to monitor the plants for symptoms of nutrient deficiencies.

Basil Diseases

Disease are one of the biggest issues that producers face when growing basil. The three biggest disease challenges for growers are fusarium wilt, gray mold, and downy mildew.

Fusarium Wilt

Fusarium wilt is a devastating fungal disease caused by *Fusarium oxysporum* f. sp. *basilicum* which is a soil borne pathogen (Tran, 2011). This is a serious disease that is found

throughout the world and can be found in field and greenhouse sweet basil production. Infected plants show epinasty, asymmetric growth, curling, chlorosis, and wilt, starting from the apical leaves (Garibaldi et al, 1997). Stunting and chlorotic leaves are the first symptoms to be visible and can develop when the plants are six to twelve inches tall. Before this stage, symptoms are not obvious and infected plants may appear normal (Tran, 2011). During the later stages of the disease there are brown streaks on stems, discoloration of stem tissue, severely twisted stems and eventually sudden leaf drop. The fungus invades the water-conducting tissue or xylem within the stem and blocks translocation of water and nutrients to the foliage.

Fusarium oxysopoum f. sp. *basilicum* is mainly a soil borne pathogen but has demonstrated movement through the air. The large number of conidia produced and frequent air circulation caused by fan operation in the greenhouse greatly facilitate dispersal of airborne propagules (Garibaldi, 1997). However, the disease is primarily introduced into all growing systems through contaminated seed.

Controlling *Fusarium* wilt is difficult as there is no cure once symptoms are apparent. It is recommended to prevent infection by practicing proper management practices as chemical controls are limited. Producers should buy and plant only basil seed that has been tested for the casual agent of *Fusarium* wilt. While testing does not guarantee that the seed is clean, it greatly reduces the risk. There are resistant cultivars available, however, using good sanitation practices in both field or greenhouse sites to minimize inoculum levels is most important (Tran, 2011). Greenhouse growers should disinfect benches and equipment between crops or immediately after outbreaks. Other prevention measures include crop rotation, soil solarization (heating soil to temperature that will kill pathogens and pests using plastic covers) and insuring proper sanitation, aeration, and drainage (Meyers, 2003). The disease is most present during, wet and

humid conditions. Any infected plants should be removed immediately and discarded because spores can splash onto other plants and infect them as well. Reducing overhead irrigation is a plus and will help with control. If Fusarium wilt becomes established in a field, crop rotation with plants other than basil or mint for two to three years can also help reducing future infections (Tran, 2011).

Gray Mold

Gray mold, caused by *Botrytis cinerea*, is a fungal disease of basil that prefers to have high relative humidity, moderately cool temperatures and poor air circulation. It can be found in both the greenhouse as well as in field production. *Botrytis cinerea* infects more than two hundred plant species and produces large numbers of conidia on conidiophores (Elad et al., 2014). The conidia are very easily disseminated in wind currents or by rain splashing from plant to plant. Saprophytic mycelia or sclerotia survive unfavorable periods on crop debris (Garibaldi et al., 1997).

Infections are more likely to occur at plant wounds and then spread to leaves and secondary buds. When the pathogen reaches the main stem, the entire plant can be killed (Tran, 2011). Since basil plants are harvested often throughout the growing season, there are many open wounds that can lead to *B. cinerea* infections. It is easily spread, not only through splashing water, but also by handling diseased plants and touching healthy plants. The most characteristic symptoms are brown to gray fungal growth on both leaves and stems. This growth usually appears as a denser, fuzzy mold than downy mildew (Tran, 2011). Eventually the leaves die and will drop from the plant. Once the disease has entered the main stem this almost always causes complete death of the plant.

Control of gray mold can be accomplished primarily through using good integrated pest management practices. There are very few fungicides that are labeled for use on herbs, including basil. When favorable conditions are present it is best to minimize working or harvesting the crop when the plants are wet. In greenhouse operations, it is important to keep the humidity at low to help control disease spread. Sanitation is key. When plants are showing symptoms, remove and discard infected plants. It is also important to sanitize equipment, and avoid overhead irrigation when possible. The disease not only affects growing plants, but can also affect harvested crops. If a harvested crop has been infected, disease may develop on the packed bunches during shipment to market, resulting in rot of the entire package (Garibaldi et al., 1997).

Downy Mildew

Basil downy mildew is caused by the obligate, biotrophic oomycete pathogen *Peronospora belbahrii* Thines (Shao et al., 2018). It is a very destructive disease that has caused severe damage and crop loss of sweet basil worldwide. Scientists view the disease as the single biggest threat to the commercially most important herb, sweet basil, in the United States (Higgins, 2015). The disease was first reported on basil in Uganda in 1932 as *Peronospora* spp. and again in 1937 as *Peronospora lamii* causing defoliation and death of sweet basil. The disease was not reported again until 2001 in Switzerland. Following this confirmation, other countries throughout the world reported first occurrences: Italy in 2003, France and Belgium in 2004, South Africa in 2005, Iran in 2006, Cameroon in 2007, Argentina in 2008, Cuba and Taiwan in 2009, Hungary in 2010, Canada in 2011, and Cyprus and Czech Republic in 2012 (Wyenandt et al., 2015). The first occurrence in the United States was confirmed in southern Florida in the fall of 2007 and has since been found throughout the United States.

Symptoms of basil downy mildew resemble and can be mistaken for a nutrient deficiency, such as nitrogen. The first major symptom that is present is the yellowing of leaves, with the discoloration often beginning around the middle vein and spreading outwards on the leaf. As the disease progresses, fuzzy grayish-purple sporangia develop on the lower surface of the leaves.

The spores can survive and travel long distances during periods of high humidity and wet conditions. Plants can be infected with the downy mildew when temperatures are between 50° F and 80° F with the optimal temperature being 60° F and 70° F. Wet weather conditions and wet plants can favor infection and subsequent spread to occur quickly. *Peronospora belbahrii* is not known to produce oospores, thus it requires a living host in order to reproduce and survive. Therefore, the pathogen can only overwinter in warm, temperate regions where basil will not freeze during cold winter months (Wyenandt et al., 2015). The overwintering of the spores only happens in the southern most parts of the United States and in greenhouses.

The use of fungicides has been utilized in the control of basil downy mildew when the label allows. These must be applied before the disease is present. There is also a very high concern of fungicide resistance because of the limited number of fungicides that are labeled for use. Thus, best control results from cultural practices that include inspecting transplants before planting, maintaining sanitation by eliminating weeds to prevent favorable microclimates (i.e., higher relative humidity and reduced air movement), destroying contaminated crops immediately to reduce disease pressure, minimizing leaf wetness and humidity in the plant canopy, increasing plant spacing, planting in an open field in full sunlight exposed to prevailing winds and using drip rather than overhead irrigation (Wyenandt et al., 2015). Recently, new cultivars touting downy mildew resistance have been released.

Good suppression of downy mildew can be obtained with new resistant varieties that started to be marketed in 2018 (McGrath, 2019). The process of introducing new resistant varieties has been of the up most importance to breeders. Sweet basil is extremely susceptible to the disease and other varieties of basil are not as susceptible, but do not have all of the marketable traits of sweet basil mainly appearance and taste. In developing basil that is less susceptible to the disease, scientist have examined plants from other basil species, including citrus basil, holy basil and a shrubby species named *Ocimum gratissimum* (Higgins, 2015). The first cultivar that was released to show moderate resistance was Elanora (Figure 6). This cultivar was at one time the best option for partial resistance to downy mildew.

Devotion, Obsession, Passion, and Thunderstruck are the first resistant cultivars release from the Rutgers University breeding program (McGrath, 2019). These cultivars have been bred with Thai basil to incorporate a downy mildew resistant gene, but yet still possess sweet basil attributes of taste and appearance. Other cultivars that are now on the market that are sold as less susceptible to basil downy mildew are Everleaf and Prospera (an Israeli bred basil).

Harvest and Post-Harvest Considerations

The part of the plant that is harvested and the timing of the harvest depend on the anticipated use of the herb. For dried basil leaves, the plant is cut just prior to appearance of flowers. To produce essential basil oil, the plant is harvested when the flowers are in full bloom. Basil leaves are harvested above the bottom two or four sets of true leaves for fresh and dried markets. In larger commercial operations, basil plants are cut four to five inches above the ground to allow for regrowth. In warmer climates, three to five cuttings can be made per year, and in cooler climates two cuttings are more likely (Simon, 1995). The entire plant may be cut at harvest depending on the market demand.

For homeowners, keeping basil plants healthy and vibrant is important. Often the flowers are pinched off to allow the plant to continue to produce leaves. Once the plant flowers, it will not continue to produce leaves. Also, during early growth stages many times the tips are pinched off to allow the plant to become bushy and full with more leaves that are marketable.

Basil is packaged in bulk boxes in the field and transferred to storage rooms below 50F for short periods without inducing chilling damage. Shipped to a packinghouse, the herb is hand sorted and placed into small plastic clam shells for retail sales. Whole plants are wrapped in plastic to maintain their integrity.

With basil being a popular culinary herb used in a variety of dishes all over the world, it is often used raw, not cooked. The consumption of contaminated basil has been linked to foodborne illnesses. The most recent outbreak caused by consumption of fresh basil occurred in Norway in 2011 and resulted in 46 human illnesses. In 2007, *Salmonella* was responsible for two international outbreaks associated with fresh basil imported from Israel, which resulted in 32 and 19 cases (De Bruin et al., 2016). To avoid such incidences happening in the future it is important to follow good agricultural and post-harvest practices from the field all the way to the consumer.

Materials and Methods

Projected Audience:

The targeted audience for this research is commercial and home growers. The expected outcome is greater information on basil cultivars that are available for growers to choose from.

Research Methodology:

Research examining eight cultivars of sweet basil occurred over the 2019 growing season. Trials were established at Adam’s Apples and Herbs in Woodstock, VA and Virginia Tech’s Eastern Shore AREC in Painter, VA. The basil was transplanted on June 13 and harvested on August 21 in Woodstock, while it was transplanted on Jun 21 and harvested on Aug 27 in Painter. More information about the eight cultivars that were tested is listed in Table 1.

Table 1. Basil Variety, seed source, and maturity size

Variety	Seed Source	Days to Maturity
Genovese	Johnny’s Selected Seed	68
Eleanora	Johnny’s Selected Seed	65
Devotion	Rutgers University	70-80
Obsession	Rutgers University	70-80
Passion	Rutgers University	70-80
Thunderstruck	Rutgers University	65-75
Everleaf	Johnny’s Selected Seed	74
Prospera	Johnny’s Selected Seed	68

The trials were arranged in randomized complete block design with four replications of each cultivar. Each plot was 15 feet long (both trials) and rows were four feet (Woodstock) or six feet (Painter) apart. Transplants were planted by hand, approximately 12 inches apart.

The plants were transplanted onto black (Woodstock) or reflective (Painter) plastic mulch. The water source for both trials was drip irrigation out of a well. Irrigation was provided every 4 to 6 days until moist across the bed throughout the season. No pesticides or fertilizers were used on the plants during the growing season. The basil was monitored twice a week

during the season for disease. During the growing season, flowers were removed until harvest in August.

Basil was harvested on August 21, 2019 in Woodstock and August 27, 2019 in Painter. Five basil plants per plot were weighed by leaf material, stem and then overall weight of the product. Figures 1-8 show the in-field growth of the eight tested cultivars at the Woodstock location. Plant heights was taken during the course of the growing season also. Data was entered into Agricultural Research Manager version 2019.3 (Gylling Data Management, Brookings, SD), analyzed using analysis of variance, with mean separations determined using Fisher's LSD ($p < 0.05$).



Figure 1. Basil cultivar "Passion" in July



Figure 2. Basil cultivar "Thunderstruck" in July



Figure 3. Basil cultivar “Everleaf” in July



Figure 4. Basil cultivar “Obsession” in July



Figure 5. Basil cultivar "Devotion" in July



Figure 6. Basil cultivar "Eleanora" in July



Figure 7. Basil cultivar “Genovese” in July



Figure 8. Basil cultivar “Prospera” in July

Results and Discussion

All eight cultivars performed consistently during the trial at Woodstock. The trial was rated twice a week for disease, however there was very little disease found on the plants during the growing season. There was another trial performed during the 2019 growing season at the ESAREC located in Painter, Virginia, where disease did occur late in the growing season(Fig. 9).

The four new cultivars that have been introduced by Rutgers University; Devotion (Fig. 5), Obsession (Fig. 4), Passion (Fig. 1), and Thunderstruck (Fig. 2) showed no symptoms of downy mildew in the Woodstock trial, with only Devotion showing some symptoms during the trial at the Painter trial. Also, at this trial Genovese and Eleanora showed symptoms of the disease. These two cultivars are known to be susceptible to downy mildew. Everleaf also exhibited symptoms of downy mildew infection on half of the plants. Prospera did not show any symptoms.

Comparing weather data for the Woodstock and Painter trials, for the months of June through August, the biggest difference was the relative humidity.

Table 2. Average daily humidity, rain, temperature for Shenandoah Valley.

TIME	HUMIDITY (%)	RAIN (IN.)	TEMPERATURE(F)
JUNE 2019	68.62%	0.04 in.	70.64 F
JULY 2019	73.38%	0.04 in.	76.16 F
AUGUST 2019	72.48%	0.04 in.	73.25 F

Table 3. Average Daily humidity, rain, and temperature Painter, Virginia.

TIME	HUMIDITY (%)	RAIN (IN.)	TEMPERATURE(F)
JUNE 2019	78.14%	0.06 in.	74.75 F
JULY 2019	82.82%	0.08 in.	78.90 F
AUGUST 2019	84.73%	0.01 in.	76.49 F

During the 2019 growing season the average relative humidity was 10% higher in Painter, Virginia than it was in the Shenandoah Valley. There was also more rain and the temperature readings were higher during the months of June, July, and August. Painter, Virginia had more favorable conditions for the downy mildew pathogen to spread and infect the plants.

The Everleaf (Fig. 3) cultivar had a more compact growth habit than the other entries. The leaf was larger than other cultivars but the total average weight of the leaves at harvest were very consistent with the other seven cultivars. The average height of the Everleaf cultivar was almost half of what the other cultivars heights in Woodstock. Everleaf had an average height of 7.6 inches compared with the next shortest, Passion, at 14.3 inches (Fig. 10).

Where Everleaf was more compact, Prospera (Fig. 8) was extremely leggy and was by far the tallest of the eight sweet basil cultivars. Prospera on average was over 1 inch taller than the other cultivars with an average height of 18.8 inches compared to the next tallest, Genovese with an average height of 17.3 inches in Woodstock.

The weight of the leaf at harvest was very similar for both trials (Fig. 11). One difference in the cultivars was the appearance of Thunderstruck. This cultivar performed very well for disease resistance, but had more of a wrinkly leaf appearance through out the growing season. Thunderstruck was also one of the better producers according to leaf weight. All cultivars were

very comparable to Genovese in weight comparisons, with Devotion, Passion, Thunderstruck, and Prospera out performing.

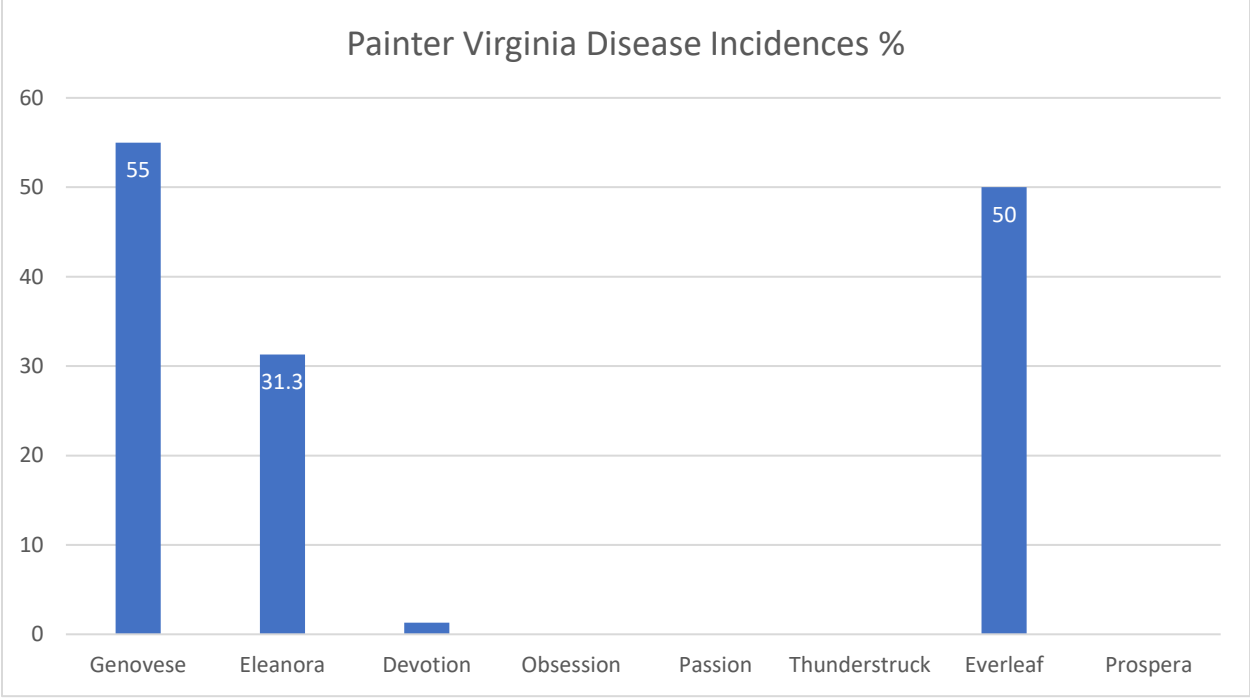


Figure 9. Disease Incidences in 2019, Painter, Virginia

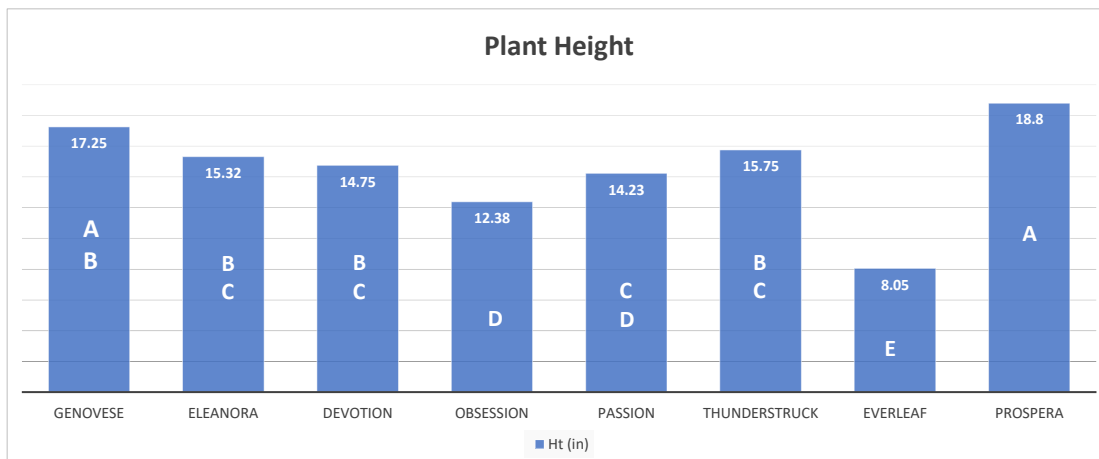


Figure 10. Average plant height during 2019 growing season, Shenandoah Valley, Virginia.

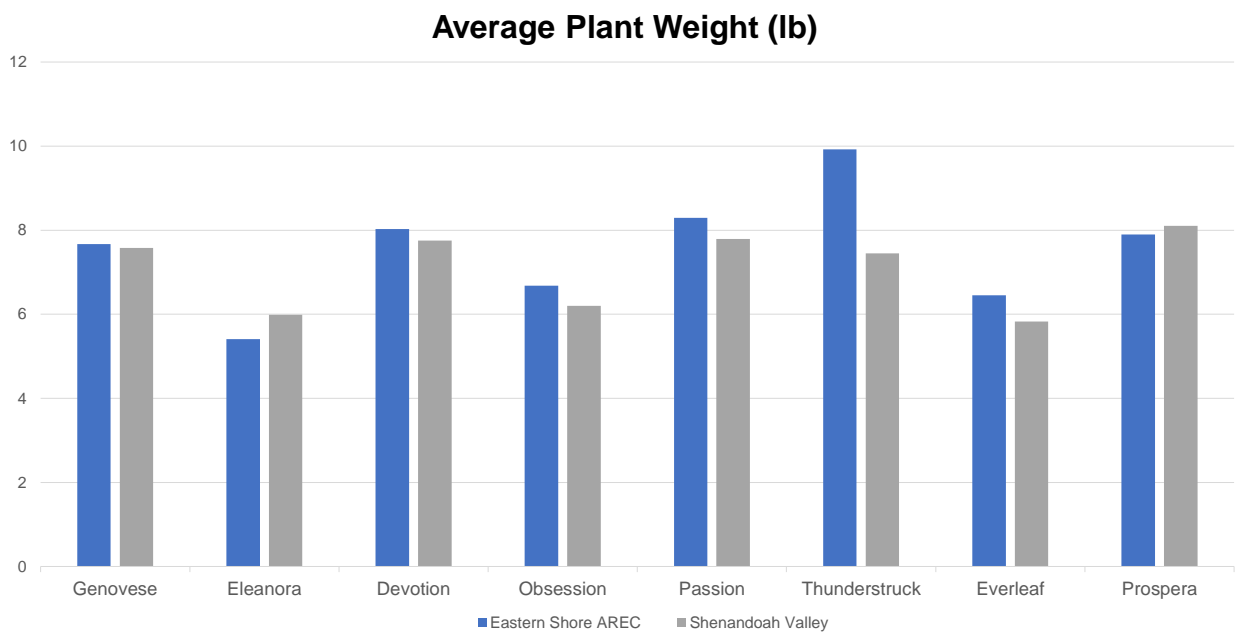


Figure 11. The comparison of total harvest between Painter, Virginia and the Shenandoah Valley Virginia in 2019.

Conclusions

Genovese and Eleanora have been two cultivars of basil that have been predominately grown. These two cultivars are susceptible to the downy mildew pathogen. The six other sweet basil cultivars have been introduced promoting resistance to downy mildew. The four new Rutgers varieties performed well with only Devotion showing some symptoms of downy mildew in the trial performed in Painter, Virginia. Everleaf, had a poor showing of downy mildew resistance at the Painter, Virginia trial and may not be a good selection for resistance. Prospera also performed well for resistance to downy mildew. Weather makes a difference on severity of downy mildew spread. The higher humidity and more rainfall in Painter, Virginia was a more favorable environment for the downy mildew pathogen to be present than in the Shenandoah Valley during the 2019 growing season. All of the new varieties that have been introduced seem to show some promise with resistance to downy mildew, with the exception of Everleaf, and also show good value in production.

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