OHIO STATE UNIVERSITY EXTENSION & OHIO AGRICULTURAL RESEARCH AND DEVELOPMENT CENTER

Hop Production Field Research Studies: 2013 - 2014

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Description

There are over 172 licensed craft brewers in Ohio, a number which continues to grow. With that, the need for ingredients is rapidly increasing. These craft brewers spend over $4 million importing hops, a main ingredient, from outside of Ohio. Hops, flowers of the hop plant, provide a bitterness that balances the sweetness of the malt sugars and a refreshing finish. Historically hops were grown in Ohio; however, they had been pushed out of the area in the early 1900's by insect and disease pressure. With better knowledge and tools to manage these problems Ohio is ready to re-claim this high-value crop. Based on the increased interest in buying locally grown and produced items, this project has provided an excellent opportunity for The Ohio State University to expand specialty crops research to include hop production. Sustainable production practices have been developed directly related to Ohio growing conditions. Data collected from our applied field research has allowed us to educate growers about production, pest management practices, and marketing. Challenges include: lack of experience with the system among growers, extension personnel and researchers, high production costs, and adaptability of suitable varieties to Ohio's climate.

Objectives of research study

In 2013 and 2014 this field research has evaluated hop production and quality for multiple varieties. Continued variety testing and crop management strategies still need to be explored and optimized to maximize grower financial returns.

Scope of Research

Two ¼ acre hop yards were established in the early spring of 2013. One at the OSU South Centers/Piketon Research & Extension Center at Piketon, Ohio (lat. 39.07° N, long. 83.01° W, elevation 578 m), and another at the Ohio Agricultural Research and Development Center (OARDC) at Wooster, OH (lat. 40.73° N, long. -81.90° W, elevation 536 m). High trellis systems (17 ft.) were installed at each site. Each hop yard consists of 10 rows of 18 plants for a total of 180 plants per hop yard. There are 10 varieties planted at each site in a complete block design with the following varieties (Figure 1):

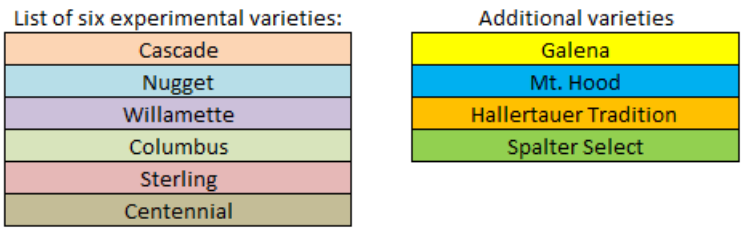


Figure 1: Varieties planted within the hop yards.

The experimental varieties are those from which we collected data. The additional varieties are planted in the border rows to protect our six experimental varieties from pesticide or herbicide drift.

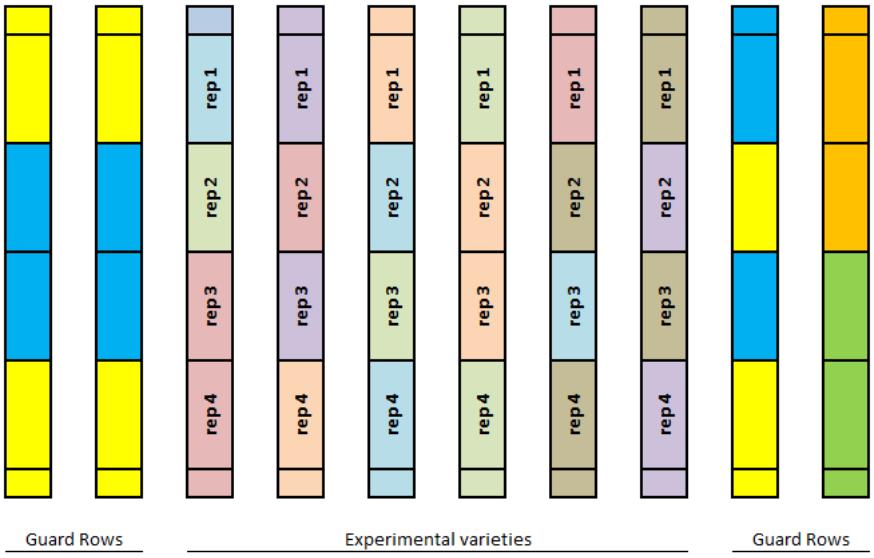


Figure 2: Wooster plots

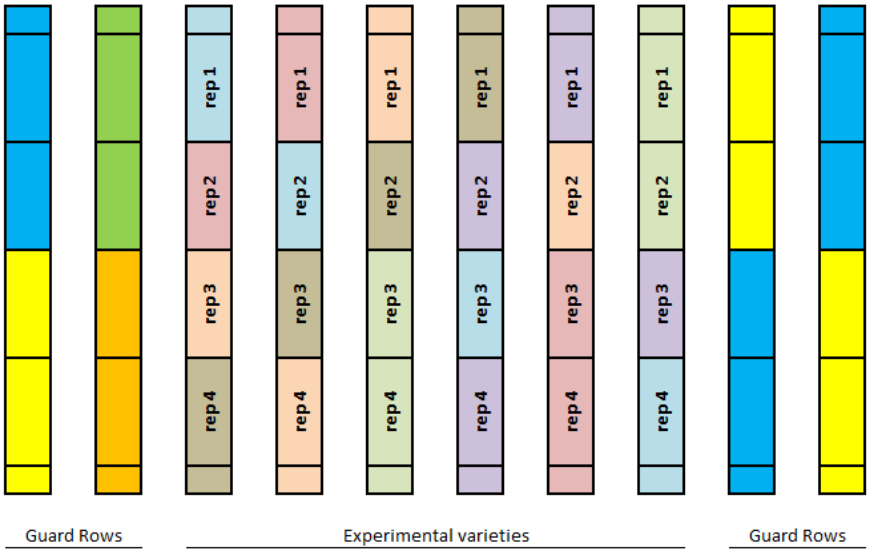


Figure 3: Piketon plots

Throughout the growing seasons the presence of arthropod pests, natural enemies (beneficial arthropods), and disease were observed and documented. Plant growth characteristics were also recorded. At each harvest, yield data were recorded. Cone quality was measured for a subsample of the varieties planted.

Methods

Planting

Before planting lime was applied to the Piketon field site at a rate of 2477 lbs. per acre (Piketon). Raised beds were built up with a commercial bed shaper to 11 inches (Piketon) and nine inches (Wooster). Landscape fabric was installed over the beds for weed control. Rhizomes were ordered from B. Crosby Hop Farm (OR, USA) and stored in a refrigerator until planting. Prior to planting, a torch was used to burn holes into the landscape fabric. The rhizomes were planted in Piketon on May 9th, and Wooster on May 8th of 2013. One rhizome was planted per hill under 1-2 inches of loosely packed soil with three feet between each hill. Five feet separates hills containing different varieties.

Pruning

In 2013 the hop plants were not pruned at any time. However, in 2014 the first growth was cut back to ground level. After training of the bines was completed the remaining untrained bines were pruned back to ground level. At the Wooster site this began on June, 17th and on May 22nd in Piketon. Pruning back excess bines continued throughout the growing season as needed. The lower two-three feet of leaves were stripped from the plants at both sites when the bines had grown at least half way up the trellis. Wooster started stripping leaves on June 24th and Piketon started on June 12th.

After harvest the vegetation left behind was pruned back to ground level. In 2013 this took place on October 29th in Wooster and November 15th in Piketon. In 2014 we waited until after the first hard frost. The fall pruning was completed on November 25th in Wooster and December 22nd in Piketon.

Training

During the 2013 and 2014 growing seasons two twines (sisal bailing twine) were dropped per plant at both sites. In 2013 training started at the Wooster site on June 5th and at the Piketon site on May 31st. Two bines were trained per twine. In 2014 training started at the Wooster site started on May 1st and at the Piketon site on May 13th. Three bines were trained per twine.

Irrigation & Fertilizer

In 2013 the Wooster site was not fertilized. Piketon applied 230 lbs. phosphorus and 140 lbs. potassium per acre prior to bed formation. 75 lbs. per acre nitrogen was applied via the drip irrigation on June 27th. In 2014 the Wooster site was fertilized by hand on June 23rd 50 lbs. per acre of nitrogen, phosphorus and potassium. Piketon applied 104 lbs. per acre nitrogen, phosphorus and potassium via the drip irrigation on May 29th. A second application of nitrogen was applied via drip irrigation on June 12th at a rate of 80 lbs. per acre.

Insecticides, Fungicides & Miticides

In 2013 we did not apply pesticides to either hop yard. In 2014 downy mildew was detected in the Wooster hop yard, the Piketon yard remained disease free. Fungicides were applied on a 7 to 10-day Schedule, according to Midwest Extension hop yard recommendations. Insecticide and miticide applications were applied when the target insects number were over the set thresholds.

Arthropod Sampling

Two leaves from the lower (0-5.5ft), middle (5.5-11ft), and upper (11-17ft) sections of the plants were collected from one randomly selected plant per repetition at each hop yard weekly in 2013 and 2014. If the plant had not reached a particular height, leaves were not collect from that section. The leaves were placed in a zip-lock bag with a label and frozen overnight. The next day, two-spotted spider mite and hop aphid were counted on each leaf. This information was used to determine if a chemical application was required to control these arthropod pests.

Vacuum sampling of one randomly selected plant per repetition was conducted biweekly throughout the growing season. A rectangle transect (1ft x 3 ft) was placed in front of the plant 3.2ft from the ground, or 1-2 inches below the highest eye of the plant if the plant was not yet that tall. The entire area within the rectangle transect was vacuumed with a modified leaf blower. Samples were transferred to a zip-lock bag and frozen. The presence of natural enemies and pests within the samples were counted.

Harvest

The bines were cut down and the cones were hand harvested. While cutting the bines down we left some vegetation in the field. We collected and analyzed yield data for the six experimental varieties in both hop yards. After the hop cones were harvested they were weighed (wet weight) and then dried with an oast (hop dryer), weighed (dry weight), packaged with a vacuum sealer, and stored in a freezer.

Chemical analysis

The hops harvested from the field research trials were analyzed for their chemical and brewing properties. This analysis was donated by two laboratories: The Portsmouth Brewing Company in cooperation with Shawnee State University Chemistry Department in Portsmouth, OH and The Actual Brewing Company in Columbus, OH.

The traditional lab protocols used for these analyses were developed for fresh leaf (undried) and pelletized hops. The hops we provided to the lab were dried whole leaf hops. Therefore, a new lab protocol was developed for whole leaf hops.

In 2013 seven western grown hop varieties commonly purchased by the Portsmouth Brewing Co. were analyzed along with one variety (Columbus) of Piketon, OH grown hops

Outcomes & significance of outcomes:

Cold Hardiness

The severe winter that Ohio experienced over 2013-14 did not appear to negatively affect spring emergence of the hops. In Wooster, 99% of the plants survived through the winter. Piketon had 100% emergence in their hop yard.

Arthropod Sampling

Neither two-spotted spider mites or hop aphids was detected prior to harvest in 2013. During the 2014 growing season hop aphids were detected at low levels, which do not lead to chemical control. However, two-spotted spider mites were detected at higher levels, particularly at the Piketon site.

Potato leaf hopper (PLH) was the most abundant pest from the vacuum samples (vacuum sampling does not collect mites or aphids). Ohio growers should scout for them weekly to avoid loss especially after any nearby alfalfa (primary host for PLH) is cut. The Wooster hop yard experienced damage due to PLH (hopper-burn) in 2013, but there was no apparent PLH damage in 2014. No economic threshold is known for PLH. The most abundant natural enemy was Araneae (spiders). Growers should consider the impact on spiders when making management decisions, as they prey on various pests such as PLH (Figure 4).

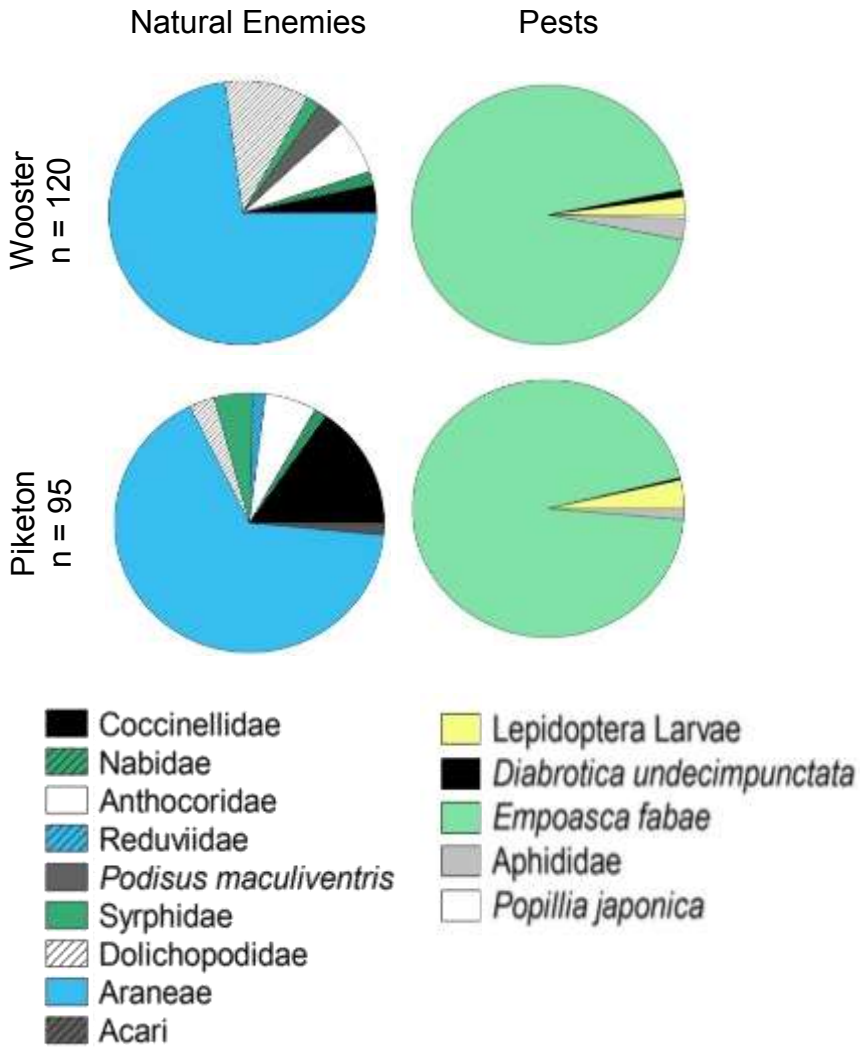


Figure 4: Natural enemies and pests from vacuum samples collected in Wooster and Piketon (2013) summed across the season. Natural enemies detected were: Coccinellidae (lady beetle), Nabidae (damsel bug), Anthocoridae (minute pirate bug), Reduviidae (assassin bug), Podisus maculiventris *(spined soldier bug), Syrphidae (hover fly), Dolichopodidae (long legged fly), Araneae (spider), and Acari (predatory mite). Pest insects detected were: Lepidoptera Larvae (moth and butterfly caterpillars),* Diabrotica undecimpunctata *(spotted cucumber beetle),* Empoasca fabae *(potato leaf hopper), Aphididae (aphid), and* Popillia japonica *(Japanese beetle)*

Harvest

The 2013 yield, being the first year of production, was low. However, this was the expected result. Hop plants typically do not produce many cones within their first year as they direct most of their energy towards producing root systems. The Columbus variety produced the highest yield. In 2014, Wooster's highest yielding variety was Columbus, while cone production by Nugget was greatest in Piketon.

This indicates that the performances of particular varieties may vary across Ohio. Yield data for 2013 and 2014 is included in the tables below:

Table 1: Hop Yields Piketon, Ohio 2013

Variety	Wet lbs./Plant	Dry lbs./Plant	Wet lbs./Acre	Dry lbs./Acre
Cascade	0.05 B	0.01 B	67 B	13 B
Nugget	0.15 B	0.04 B	183 B	54 B
Columbus	0.92 A	0.17 A	1118 A	216 A
LSD	**0.45**	**0.09**	**551**	**120**

*Values with the same letter are not significantly different

Table 2: Hop Yields Wooster, Ohio 2013

Variety	Wet lbs./Plant	Dry lbs./Plant	Wet lbs./Acre	Dry lbs./Acre
Cascade	0.117 B	0.0271 B	142 B	32.86 B
Nugget	0.1 B	0.0231 B	122 B	28.01 B
Williamette	0.002 B	0.0005 B	3.6 B	0.72 B
Columbus	0.702 A	0.1655 A	850 A	200.25 A
Centennial	0.041 B	0.0104 B	50 B	12.61 B
LSD	**0.203**	**0.0423**	**246**	**51.19**

*Values with the same letter are not significantly different

Table 3. Hop yields from Piketon and Wooster Ohio 2013.

Variety	Wet lbs./Plant	Dry lbs./Plant	Wet lbs./Acre	Dry lbs./Acre
Galena Piketon	0.40 A	0.1 A	490 A	126 A
Galena Wooster	0.33 A	0.08 A	401 A	97 A
LSD	**0.47**	**0.08**	**572**	**99**

*Values with the same letter are not significantly different

Table 4: Hop yields from Piketon Ohio 2014.

Variety	Wet lbs./Plant	Dry lbs./Plant	Wet lbs./Acre	Dry lbs./Acre
Nugget	1.92 A	0.57 A	2323 A	693.62 A
Columbus	1.15 B	0.36 B	1396 B	438.09 B
Cascade	0.78 BC	0.30 B	955 BC	371.8 B
Sterling	0.62 C	0.17 C	757 C	215.55 C
Centennial	0.23 D	0.08 CD	283 D	101.28 CD
Williamette	0.09 D	0.02 D	118 D	24.99 D
LSD	**0.38**	**0.1**	**468**	**128.87**

*Values with the same letter are not significantly different.

Table 5: Hop yields from Wooster Ohio 2014.

Variety	Wet lbs./Plant	Dry lbs./Plant	Wet lbs./Acre	Dry lbs./Acre
Columbus	2.69 A	1.01 A	3264 A	1225 A
Nugget	1.98 B	0.64 B	2405 B	775 B
Cascade	1.29 C	0.41 C	1562 C	507 C
Sterling	0.58 D	0.18 D	702 D	221 D
Williamette	0.46 DE	0.13 DE	557 DE	169 DE
Centennial	0.14E	0.04 E	174 E	53 E
LSD	**0.39**	**0.13**	**475**	**159**

*Values with the same letter are not significantly different.

Table 6: Hop yields from Piketon and Wooster Ohio 2014.

Variety	Wet lbs./Plant	Dry lbs./Plant	Wet lbs./Acre	Dry lbs./Acre
Galena Piketon	0.95 A	0.29 A	1160 A	352 A
Galena Wooster	0.87 A	0.24 AB	1056 A	302 AB
Mt. Hood Wooster	0.34 A	0.10 AB	418 A	121 AB
Mt Hood Piketon	0.13 A	0.03 B	157 A	37 B
LSD	**0.9216**	**0.2587**	**1115.1**	**313**

*Values with the same letter are not significantly different.

Chemical analysis

In 2013 seven western grown hop varieties commonly purchased by the Portsmouth Brewing Co. were analyzed along with one variety (Columbus) of Piketon, OH grown hops (Table 7). The % alpha content in the Piketon sample detected by the lab analysis was 6.8% which is low in comparison to the typical amount of 14.5-15.5% for the brewing industry.

In 2014 fresh hop samples were analyzed by the Actual Brewing Company in Columbus, OH for chemical and brewing characteristics. Using spectrophotometry, the % concentration of alpha and beta acids, storage index, original % alpha acid, and % alpha acids lost were performed comparing Piketon grown and western grown hops. Initially, these lab analyses indicated that the chemical properties of Piketon hops were low in comparison to western grown hops when ICE or international artificial hop standard standards were compared. ICE-3 is an international artificial hop standard that allows breweries to calibrate hop measuring equipment.

However, in addition to the lab analyses, Master Brewer Fred Lee performed a professional sensory analysis. From this analysis Mr. Lee indicated that the Piketon hops were of exceptional quality, which contradicted the lab analysis. This indicates that the lab protocols need to be improved or the moisture level in

the Piketon sample was too high to get an accurate alpha acid measurement. The % alpha content is typically measured when the hops are at 8% moisture content. It is likely that the Piketon samples had >8% moisture content. The leafy nature of the Piketon hops may have also prevented us from fully extracting the acids.

From these early chemical analysis results we determined that whole leaf hops should be pulverized using a hammer mill apparatus to better extract the alpha acids. To aid in future analysis, a protocol using a soil grinder/shredder is now used to pulverize the leafy hop samples prior to testing to achieve a more accurate extraction and analysis.

Table 7: Chemical analysis report (2013). The Piketon sample is highlighted in yellow

Variety	Typical %Alpha	Typical %Beta	%Alpha	%Beta
Perle	7.0 - 9.5	4.0 - 5.0	7.4	3.9
Cascade	4.5 - 7.0	4.8 - 7.0	4.9	7.1
Kent Goldings	4.0 - 6.0 (US)	2.0 - 3.0 (US)	6.3	2.6
Tettnang	4.0 - 5.0	3.0 - 4.0	4.9	3.1
Czech Saaz	3.0 - 4.5 (US)	3.0 - 4.5 (US)	2.4	4.6
Perle	7.0 - 9.5	4.0 - 5.0	7.3	3.9
GR Hallertau	3.5 - 5.5 (US)	3.5 - 5.5 (US)	5.7	5.5
Columbus	14.5 – 16.5	4.0 - 5.0	6.8	2.1

Table 8: Monthly rainfall totals from Wooster (2013, 2014)

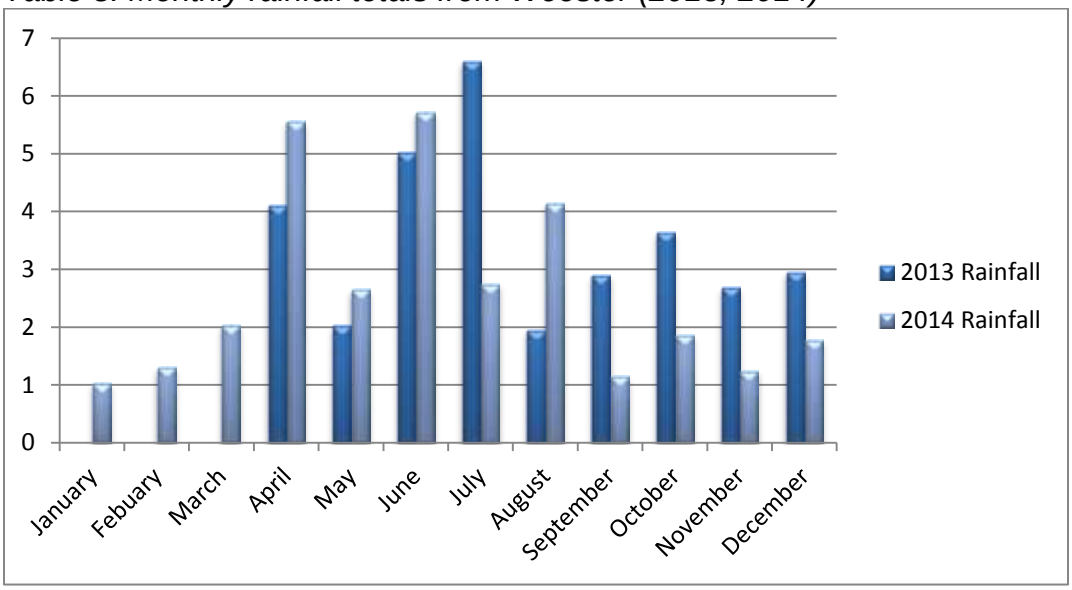


Table 9:. Monthly rainfall totals from Piketon (2013, 2014)

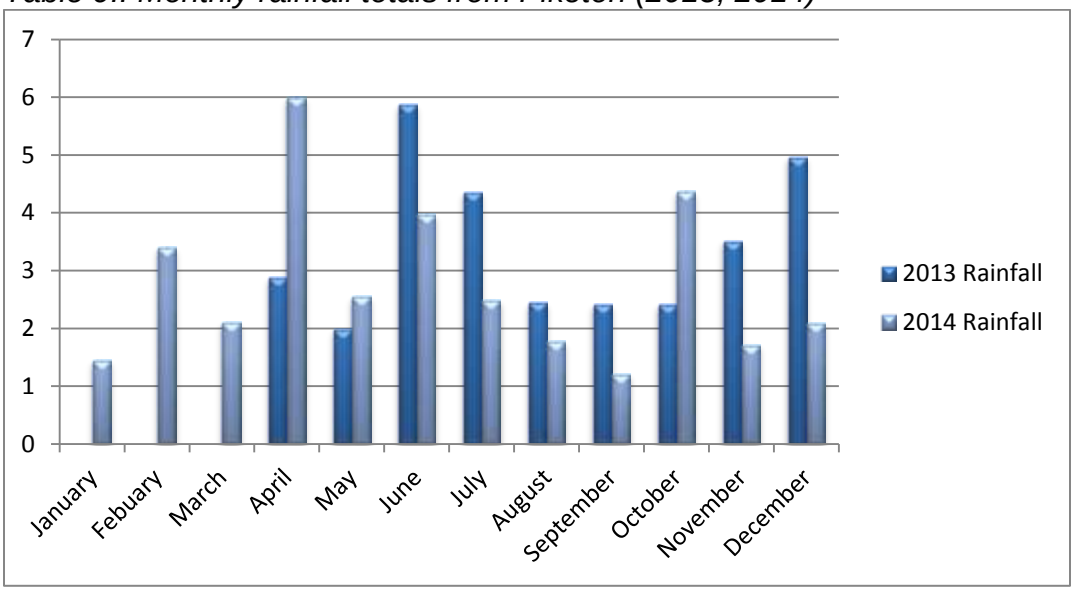


Table 10: Monthly temperatures for Wooster (2013)

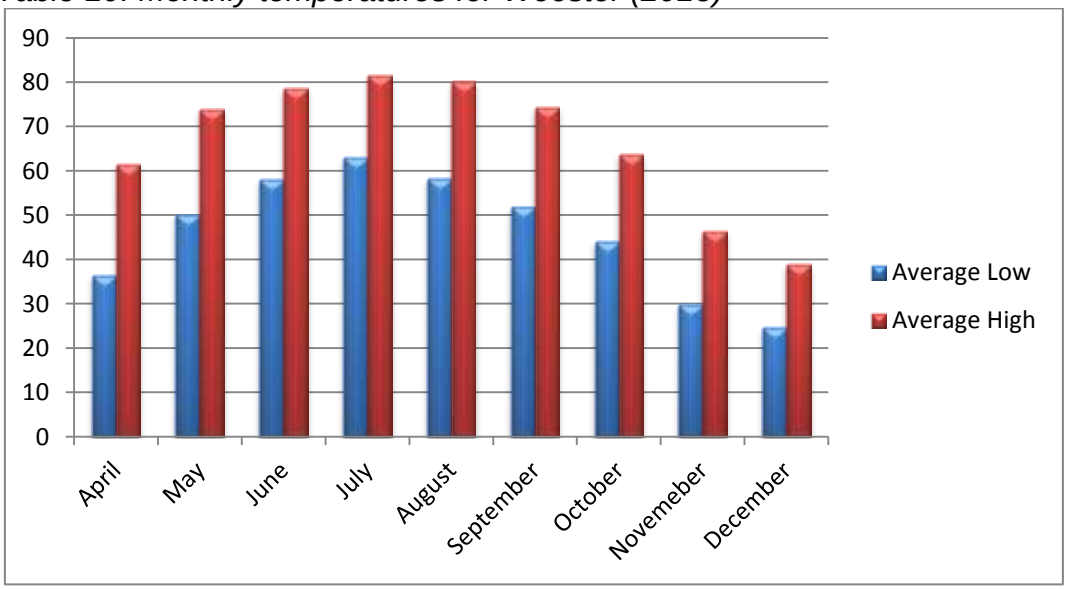


Table 11: Monthly temperatures for Wooster (2014)

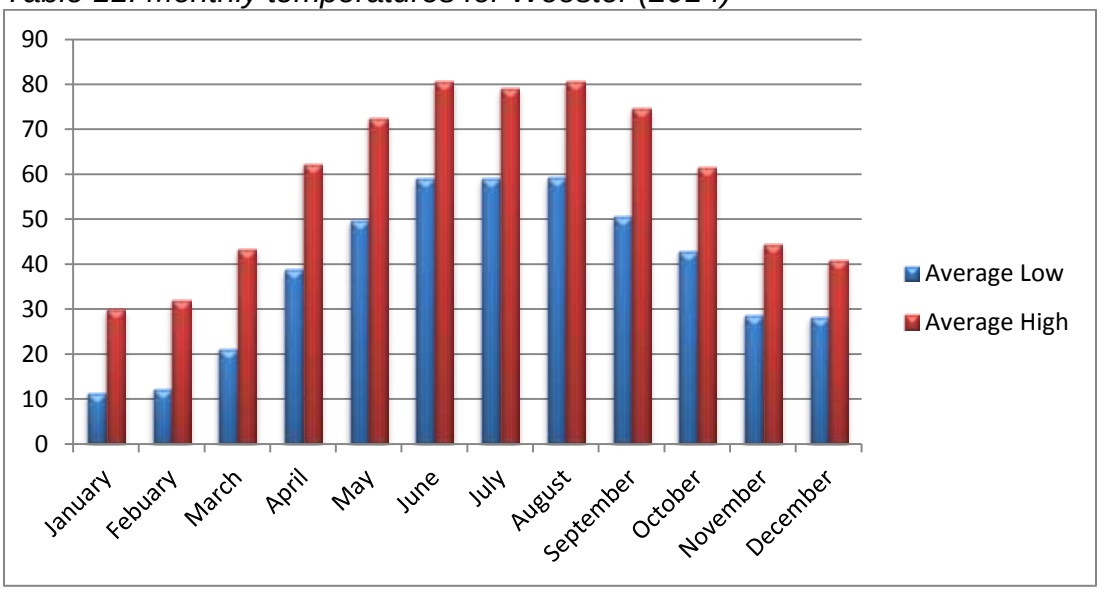


Table 12: Monthly temperatures for Piketon (2013)

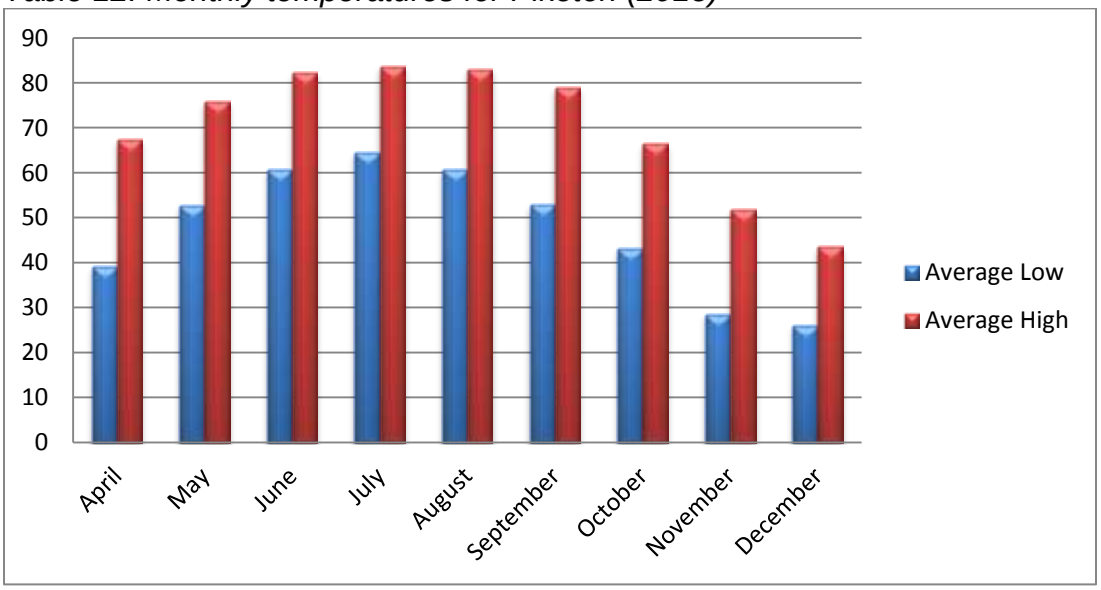
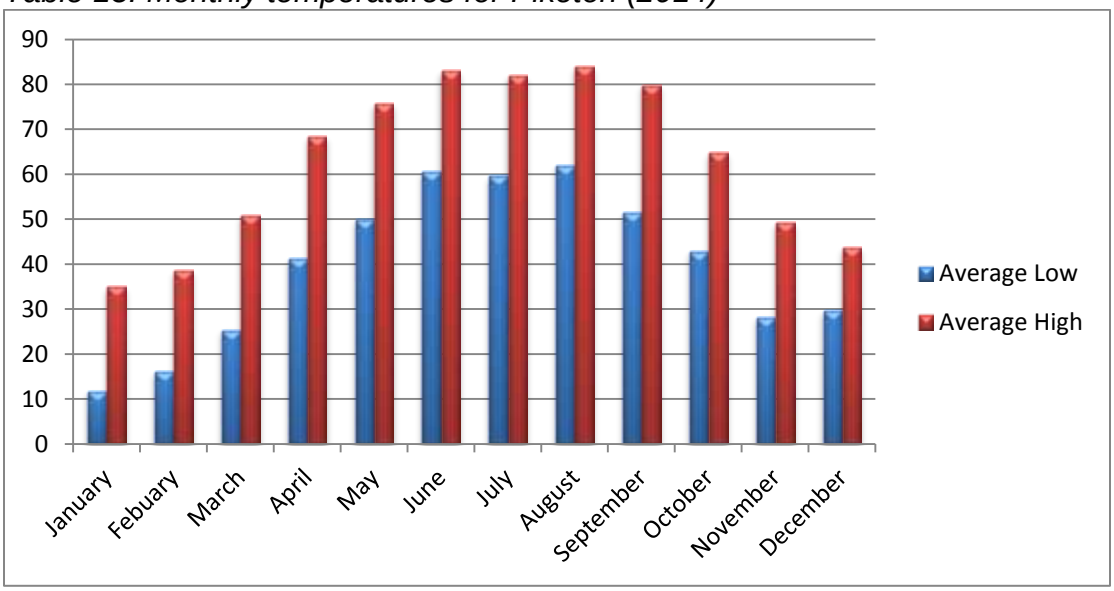


Table 13: Monthly temperatures for Piketon (2014)



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