Marketing and Orchard Resource Efficiency for Ohio Pawpaw

Brad R. Bergefurd, Horticulture Specialist and Extension Educator, South Centers
Matt Davies, Assistant Professor, The Ohio State University
Thomas Harker, Horticulture Research Associate, South Centers
Sarah Francino, Graduate Research Associate, The Oho State University

Objectives of research study:
This study will:
1) Evaluate pawpaw productivity, fruit quality, and disease susceptibility of 12 commercial pawpaw cultivars. Best practices for pawpaw orchard establishment have been determined and implemented in both Columbus and Piketon, Ohio.
2) Quantify inter- and intra-annual variation in woodland pawpaw productivity at multiple sites across Ohio. Permanent monitoring plots have been established at X different locations and monitoring completed for up to X years. Monitoring in 2018 and 2019 was supported by this project

Scope of Research:
The orchard study was conducted at the Ohio State University (OSU) South Centers Research and Extension Center in Piketon, Ohio (lat. 39.07° N, long. 83.01° W), elevation 578 feet. The experimental soil is designated as a DoA — Doles silt loam, with 0–3% slopes. It is a deep, nearly level, and somewhat poorly drained soil. Typically, the soil surface is a brown, friable silt loam about 20 cm deep and beneath this the subsoil is about 18.5 m.
The orchard was replicated at The Ohio State University's Waterman Agricultural and Natural Resource Laboratory (Waterman Farm). The field consists of a mixture of soil types including: 62.6% Celina silt loam, 2-6 % slopes, eroded; 9.6% Crosby silt loam, Southern Ohio Till Plain, 2-6 % slopes; and 27.8% Kokomo silty clay loam, 0-2% slopes. Drainage ranges from "moderately well" to "somewhat poorly" to "very poorly." The SE corner of the plot has the coordinates: lat 40.007208, long 83.038029 and an average elevation of 779.39 (range: 771.31-791.21 ft).

Woodland monitoring was completed within woodlots at Waterman Farm, OSU South Centers, OSU's Olentangy River Wetlands Research Park (Lat/Long), Foxpaw Farm (Lat/Long), Integration Acres (Lat/Long)

Materials and Methods:
Cultivar selections were new releases along with industry standard varieties. Input was received from growers and industry personnel regarding variety selection and standard comparison.

Two one-acre pawpaw orchards were established in the spring of 2018 at the Waterman Agriculture and Natural Resources Laboratory (Columbus, OH) and OSU South Centers (Piketon, OH). Trees were planted May 30th (Columbus) and June 6th (Piketon) of 2018. Each orchard consists of two planting types, high and low input orchard planting systems. The high input method consists of a raised bed 11 in. high at the Piketon location and 6 in. high at the Columbus location. Placing the trees on raised

beds helps with drainage of water away from the tree roots. Landscape fabric was applied to the raised beds using a bed shaper, which is traditionally used in the vegetable industry. Landscape fabric is a material that covers the ground, but allows water to permeate through the fabric. The idea behind the fabric was to provide weed control, as there is only one registered herbicide available for pawpaw. The fabric also assists with water retention in the soil. Two irrigation drip lines were placed on the edge of the planting bed. The irrigation drip lines are a hard, orchard-type tubing with emitters spaced 30 in. apart with a .53 gal per hour flow rate. Irrigation water was sourced from a well (Columbus) and a reservoir (Piketon). Both locations attempted to maintain one inch of water per week by natural or drip irrigation. Timers were purchased and installed at Piketon in fall 2019 so that irrigation can be set up on a schedule. Timers will be installed at the Columbus location in spring 2020. The low input method is a flat planting bed with no irrigation. The only water that the low input part of the study would have been from rainfall. Soil fertility was applied according to the soil test results for each location. Fertility levels at the Columbus orchard are high at this time, so no additional fertility was required at planting. Prior to the formation of raised beds, 62 lb of 18-46-0, and 106 lb of 0-0-60, were applied in row at the Piketon orchard. With very few chemical options for weed control at this time, weeds were controlled with roundup applications, rototilling, and hand removal. Sod was established between all rows with a fall seeding. Rows are spaced on 15 ft centers with 10 ft separating the trees in the row. This makes for a plant population of 290 trees per acre. A survival survey of trees was taken in fall 2018 and replacement trees were purchased. Replanting was conducted spring 2019 at both locations. A final survival survey was taken at both locations and replacement trees to be replanted spring of 2020 were purchased.

Woodland production used an established network of woodland pawpaw monitoring sites across central and southern Ohio. Each site consists of 5-6 plots selected to represent a gradient of forest and pawpaw-patch structures from open to closed woodland canopies and young to established pawpaw trees. An Adaptive Management process was used to track the success of methods to improve fruit production. Interventions were targeted to specific site conditions and included hand-pollination, thinning of competing sub-canopy vegetation (principally invasive honeysuckle species), and grafting of commercial varietals. Grafting was completed during the summer of 2019 and survival and growth of the grafts will be evaluated in continuing studies. In the established plots we counted the number of fruit clusters and total fruit produced by each pawpaw tree and measured the trees' size (diameter-at-breast-height) and branching architecture (number of primary branches). In the spring of 2018 we additional counted the number of flowers produced by each tree to evaluate the effect of flowering effort on subsequent fruit-set.

Figure 1. Columbus soil test results.

a&lgreatlakes
LABORATORIES
Scientists who don't mind getting dirty.™

3505 Conestoga Dr.
Fort Wayne, IN 46808
260.483.4759
algreatlakes.com

To: TAPLOGIC, LLC
90 SPRUCE ST
MURRAY, KY 42071-3505

For: 109535
Farm: DO NOT ADJUST: WATERMAN D
Field: SOUTH FARM

Date Received: 10/17/2018
Date Reported: 10/19/2018

109535

Attn: LUKE CHOATE

SOIL TEST REPORT

Page: 1 of 3

Sample ID	Lab Number	Organic Matter %	Phosphorus Bray-1 Equiv ppm	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	Soil pH (1:1 H2O)	Buffer pH (Sikora)	Cation Exchange Capacity meq/100g	Cation Saturation % K	% Mg	% Ca	% Na	% H	Sulfur S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm
231-1	59856	6.0	145 VH	538 VH	440 H	2100 M		7.5		15.5	8.9	23.6	67.5								
232-1	59857	7.1	89 VH	231 H	415 H	2250 M		7.5		15.3	3.9	22.6	73.5								
267-1	59858	3.0	113 VH	239 VH	290 H	1450 M		7.0		10.3	6.0	23.5	70.5								
267-2	59859	3.8	92 VH	288 VH	310 H	2150 H		7.3		14.1	5.2	18.4	76.4								
267-3	59860	2.5	96 VH	134 M	385 VH	1500 M		7.0		11.1	3.1	29.0	67.9								
267-4	59861	2.4	147 VH	234 VH	305 VH	1350 M		7.3		9.9	6.1	25.7	68.2								
267-5	59862	3.2	238 VH	931 VH	485 H	2000 L		6.2	6.7	20.0	11.9	20.2	49.9		18.0						
267-6	59863	2.7	153 VH	286 VH	430 H	1800 M		7.4		13.3	5.5	26.9	67.6								
267-7	59864	2.9	115 VH	207 H	480 VH	1850 M		7.5		13.8	3.9	29.0	67.1								
267-8	59865	3.1	185 VH	240 VH	355 H	1950 M		7.1		13.3	4.6	22.2	73.2								
267-10	59866	3.4	173 VH	322 VH	410 H	1900 M		7.2		13.7	6.0	24.9	69.1								
267-11	59867	3.5	218 VH	373 VH	395 H	2000 M		7.0		14.2	6.7	23.1	70.2								
267-12	59868	3.7	200 VH	256 VH	270 H	1550 M		6.4	6.9	11.9	5.5	19.0	65.4		10.1						
267-13	59869	2.9	110 VH	186 H	310 H	1650 M		7.5		11.3	4.2	22.8	72.9								
267-14	59870	4.9	114 VH	230 VH	355 VH	1650 M		7.1		11.8	5.0	25.1	69.9								
267-15	59871	4.2	95 VH	271 VH	465 VH	1900 M		6.8		14.5	4.8	26.7	65.5		3.0						

VL = Very Low   L = Low   M = Medium   H = High   VH = Very High

Figure 2. Piketon soil test results.

Spectrum Analytic
1087 Jamison Road NW
Washington Court House, OH 43160-8748
www.spectrumanalytic.com

Report To
THE OHIO STATE UNIVERSITY SOUTH CENTERS
1864 SHYVILLE RD
PIKETON, OH 45661

Prepared For
OSU SOUTH CENTERS

Sampled 04-30-2018
Tested 05-01-2018

Sample Number	Lab Number	Soil pH	Buffer pH	Organic Matter %	Phosphorus P	Potassium K	Magnesium Mg	Calcium Ca	CEC	Base Saturation K %	Mg %	Ca %	Sulfur S	Boron B	Zinc Zn	Iron Fe	Copper Cu	Mang. Mn	Alum. Al
PAWPAW	D49741	5.6	6.9	1.0	30 M	79 M	212 G	712 G	5.6	3.0	27.8	47.7							

* P, K, Mg and Ca are extracted by Mehlich-3 (ICP) and are reported in ppm

Sample Number	Lab Number	Year	Crop	Yield Goal	Acres	CaCO3** Lime	N	P2O5	K2O	Mg	S	B	Cu	Fe Foliar	Mn Row	Zn
PAWPAW	D49741	18	PawPaw	0	1	2317	40	103	228	0						

*Lime expressed in 100% pure CaCO3. Adjust accordingly. D = Dolomitic Lime. C = Calcitic Lime.

Figure 3. Columbus orchard.

High Input

Rep																												Rep
Rep 1	5	8	13	6	18	12	2	14	20	4	10	27	19	23	17	7	1	21	22	25	24	9	26	14	3	16	11	Rep 1
Rep 2	6	9	8	2	19	13	26	27	21	20	15	3	22	17	12	23	7	5	18	11	14	1	25	4	24	16	10	Rep 2
Rep 3	19	18	8	12	22	20	16	14	7	13	25	21	11	23	26	4	9	1	6	24	2	15	17	10	27	5	3	Rep 3
rep 4	13	27	19	9	16	17	6	10	24	25	8	15	21	23	12	18	11	14	26	7	22	1	20	3	5	2	4	rep 4
rep 5	24	11	27	16	18	5	10	19	25	22	21	4	2	1	6	13	23	7	26	12	14	20	15	9	17	8	3	rep 5

Low Input

Rep																												Rep
Rep 1	5	8	13	6	18	12	2	14	20	4	10	27	19	23	17	7	1	21	22	25	24	9	26	14	3	16	11	Rep 1
Rep 2	6	9	8	2	19	13	26	27	21	20	15	3	22	17	12	23	7	5	18	11	14	1	25	4	24	16	10	Rep 2
Rep 3	19	18	8	12	22	20	16	14	7	13	25	21	11	23	26	4	9	1	6	24	2	15	17	10	27	5	3	Rep 3
rep 4	13	27	19	9	16	17	6	10	24	25	8	15	21	23	12	18	11	14	26	7	22	1	20	3	5	2	4	rep 4
rep 5	24	11	27	16	18	5	10	19	25	22	21	4	2	1	6	13	23	7	26	12	14	20	15	9	17	8	3	rep 5

Figure 4. Piketon orchard.

High Imput

Guard	5	8	13	6	18	12	2	14	20	4	10	27	19	23	Guard
Guard	17	7	1	21	22	25	1	9	26	14	3	16	11	6	Guard
Guard	9	8	2	19	13	26	27	21	20	15	3	22	17	12	Guard
Guard	23	7	5	18	11	14	24	25	4	24	16	10	19	18	Guard
Guard	8	12	22	20	16	14	7	13	25	21	11	23	26	4	Guard
Guard	9	1	6	24	2	15	17	10	27	5	3	13	27	19	Guard
Guard	9	16	17	6	10	24	25	8	15	21	23	12	18	11	Guard
Guard	14	26	7	22	1	20	3	5	2	4	24	11	27	16	Guard
Guard	18	5	10	19	25	22	21	4	2	1	6	13	23	7	Guard
Guard	26	12	14	20	15	9	17	8	3	x	x	x	x	x	Guard

Low Imput

Guard	26	8	13	6	18	12	2	14	20	4	10	27	19	23	Guard
Guard	5	7	1	21	22	25	24	9	26	14	3	16	11	6	Guard
Guard	17	8	2	19	13	26	27	21	20	15	3	22	17	12	Guard
Guard	9	7	5	18	11	14	1	25	4	24	16	10	19	18	Guard
Guard	23	12	22	20	2	14	7	13	25	21	11	23	26	4	Guard
Guard	8	1	6	24	16	15	17	10	27	5	3	13	27	19	Guard
Guard	9	16	17	6	10	24	25	8	15	21	23	12	18	11	Guard
Guard	9	26	7	22	1	20	3	5	2	4	24	11	27	16	Guard
Guard	14	5	10	19	25	22	21	4	2	1	6	13	23	7	Guard
Guard	18	12	14	20	15	9	17	8	3	x	x	x	x	x	Guard

Cultivars planted within the orchards.

KSU Atwood	KSU Benson
Kentucky Champion	Mango
Potomac	Rappahannock
Wabash	Shenandoah
Summer Delight	Sunflower
Allegheny	Susquehanna

Remaining 15 treatments are rootstock to be grafted

Trees were purchased from the following nurseries:

England's Orchard and Nursery
2338 Highway 2004
McKee, KY 40447
606-965-2228

One Green World
6469 SE 134th Ave
Portland, OR 97236
877- 353-4028

Table 1. Soil Moisture Columbus Orchard.

Date of Collection	Treatment	Soil Moisture (VWC)
7/29/2019	High	12.8
7/29/2019	Low	12.9
8/15/2019	High	12.3

Date	Treatment	Value
8/15/2019	Low	10.4
8/16/2019	High	18.1
8/16/2019	Low	11.6
8/18/2019	High	18.0
8/18/2019	Low	10.2
9/8/2019	High	15.5
9/8/2019	Low	15.0
9/26/2019	High	22.3

Table 2. Soil Moisture Piketon Orchard.

Date of Collection	Treatment	Soil Moisture (VWC)
10/3/2019	High	33.5
10/3/2019	Low	14.8

Table 3. Piketon Growth Measurements.

Cultivar	Input	Diameter at 30 cm.	Height cm.	Diameter at Base
Seedling	high	8.842 BA	90.9 A	20.616 BDAC
Seedling	high	6.887 EBDAGCF	81.15 BA	16.838 EBDACF
Seedling	high	7.842 EBDAC	81.1 BA	18.304 EBDAC
Seedling	high	9.816 A	80.2 BAC	21.572 BA
Potomac	high	7.112 EBDACF	77.15 BDAC	12.692 KEJBIDHAGCF
Seedling	high	6.243 EBIDHAGCF	74.15 EBDAC	13.602 EBIDHAGCF
Seedling	high	6.364 EBDHAGCF	70.25 EBDACF	16.932 EBDACF
KSU Atwood	high	5.01 EBIDHJGCF	65.35 EBDAGCF	10.974 KEJBIDHGCF
Potomac	low	5.093 EBIDHJGCF	65 EBDAGCF	7.54 KEJIHGF
Shenandoah	high	7.772 EBDAC	65 EBDAGCF	21.7 BA
KY Champion	high	5.873 EBIDHJGCF	64.1 EBDAGCF	12.534 KEJBIDHAGCF
Seedling	high	6.626 EBDHAGCF	63.35 EBDHAGCF	15.068 EBDHAGCF
KSU Benson	high	8.401 BAC	63.25 EBDHAGCF	21.272 BAC
Seedling	high	5.614 EBIDHJGCF	62.1 EBDHAGCF	13.818 EBIDHAGCF
Susquehanna	high	8.009 BDAC	62.05 EBDHAGCF	22.568 A
Seedling	high	5.256 EBIDHJGCF	61.95 EBDHAGCF	16.61 EBDACF
Shenandoah	low	6.999 EBDACF	61.3 EBDHAGCF	13.12 EBIDHAGCF
Seedling	low	6.069 EBIDHJGCF	60.3 EBDHAGCF	10.94 KEJBIDHGCF
Seedling	high	5.202 EBIDHJGCF	59.1 EBIDHJGCF	12.286 KEJBIDHAGCF
Seedling	high	5.912 EBIDHJGCF	58.55 EBIDHJGCF	15.174 EBDHAGCF
Seedling	high	5.768 EBIDHJGCF	58.2 EBIDHJGCF	18.222 EBDAC
Summer Delight	high	5.727 EBIDHJGCF	57.1 EBIDHJGCF	10.324 KEJIDHGCF
Seedling	high	5.07 EBIDHJGCF	55.1 EBIDHJGCF	12.598 KEJBIDHAGCF
Seedling	low	6.251 EBIDHAGCF	54.9 EBIDHJGCF	14.288 EBIDHAGCF
Sunflower	high	5.076 EBIDHJGCF	54.8 EKBIDHJGCF	15.692 EBDAGCF
Wabash	high	6.057 EBIDHJGCF	54.55 EKBIDHJGCF	10.802 KEJBIDHGCF

Seedling	high	5.59 EBIDHJGCF	52.65 LEKBIDHJGCF	13.332 EBIDHAGCF
Seedling	high	6.245 EBIDHAGCF	51.7 LEKBIDHJGCF	10.786 KEJBIDHGCF
Seedling	low	6.388 EBDHAGCF	51.35 LEKBIDHJGCF	9.968 KEJIDHGF
Seedling	low	4.495 EIDHJGF	50.85 LEKBIDHJGCF	10.466 KEJIDHGCF
Allegheny	low	5.901 EBIDHJGCF	50.6 LEKBIDHJGCF	12.828 EJBIDHAGCF
Seedling	low	4.615 EIDHJGCF	49.25 LEKIDHJGCF	10.028 KEJIDHGF
Seedling	low	5.06 EBIDHJGCF	48.2 LEKIDHJGF	8.02 KEJIHGF
Seedling	low	3.833 IHJGF	46.75 LEKIDHJGF	7.556 KEJIHGF
Summer Delight	low	4.187 EIDHJGF	46.5 LEKIDHJGF	7.54 KEJIHGF
KSU Atwood	low	4.81 EIDHJGCF	46.35 LEKIDHJGF	9.196 KEJIHGF
Seedling	low	4.603 EIDHJGCF	46.15 LEKIDHJGF	9.524 KEJIHGF
Allegheny	high	4.788 EIDHJGCF	45.95 LEKIDHJGF	13.67 EBIDHAGCF
Mango	high	5.33 EBIDHJGCF	45.5 LEKIDHJGF	13.818 EBIDHAGCF
Rappahannock	high	4.032 EIHJGF	44.9 LEKIHJGF	10.468 KEJIDHGCF
Seedling	low	4.751 EIDHJGCF	43.95 LEKIHJGF	9.092 KEJIHGF
Seedling	low	3.809 IHJGF	41.15 LKIHJGF	8.352 KEJIHGF
Susquehanna	low	4.381 EIDHJGF	40.85 LKIHJGF	11.484 KEJBIDHGCF
Seedling	low	3.01 IHJG	38.4 LKIHJGF	4.102 KJIH
Sunflower	low	4.283 EIDHJGF	37.8 LKIHJG	8.158 KEJIHGF
Seedling	low	3.962 EIHJGF	37.75 LKIHJG	5.872 KJIHGF
KY Champion	low	4.284 EIDHJGF	37.05 LKIHJG	8.462 KEJIHGF
Seedling	low	3.304 IHJGF	35.35 LKIHJG	6.746 KJIHGF
KSU Benson	low	3.753 IHJGF	31.6 LKIHJ	7.31 KEJIHGF
Rappahannock	low	4.123 EIDHJGF	28.7 LKIJ	5.834 KJIHGF
Seedling	low	2.893 IHJ	27.85 LKJ	4.76 KJIHG
Seedling	low	2.347 J	27.35 LKJ	3.554 KJI
Mango	low	2.389 IJ	23.3 LK	1.892 KJ
Wabash	low	2.249 J	22.35 L	1.612 K

All results with the same letter are not significantly different.

Table 4. Piketon Height Measurement's from base.

Cultivar	Input	Sample Date	Mean	Std Dev	Input	Mean	Std Dev
KSU Atwood	High	March	68.6	11.63	Low	47.9	9.40
KSU Atwood	High	July	62.1	36.44	Low	44.8	25.37
Shenandoah	High	March	58.2	6.38	Low	57.5	3.84
Shenandoah	High	July	71.8	27.87	Low	65.1	11.94
Sunflower	High	March	42.1	5.52	Low	39.3	7.76
Sunflower	High	July	67.5	15.63	Low	36.3	21.73
Susquehanna	High	March	47.6	16.36	Low	39.5	7.67
Susquehanna	High	July	76.5	26.45	Low	42.2	25.68
Seedling	High	March	35.8	35.01	Low	37.1	14.98

Seedling	High	July	74.4	45.33	Low	17.6	24.36
Seedling	High	March	54.7	14.44	Low	53.2	18.33
Seedling	High	July	72	10.22	Low	40.3	39.61
Seedling	High	March	66.3	10.87	Low	42.9	26.53
Seedling	High	July	96	22.34	Low	49.4	31.83
Seedling	High	March	53.3	17.25	Low	59.2	25.32
Seedling	High	July	63.1	22.70	Low	37.2	46.07
Seedling	High	March	40.6	18.23	Low	33.3	25.05
Seedling	High	July	76.5	32.30	Low	37.4	35.01
Seedling	High	March	52.6	32.92	Low	48.5	30.65
Seedling	High	July	87.9	33.22	Low	53.2	35.72
Seedling	High	March	44.7	29.98	Low	60.8	13.13
Seedling	High	July	65.1	53.85	Low	57.4	34.50
KY Champion	High	March	73	11.08	Low	31.7	32.31
KY Champion	High	July	55.2	38.67	Low	42.4	44.56
Seedling	High	March	64.8	27.91	Low	53.1	31.05
Seedling	High	July	83.5	61.78	Low	49.6	31.22
Seedling	High	March	51.8	23.17	Low	54	22.37
Seedling	High	July	72.4	32.18	Low	22.8	32.01
Seedling	High	March	67.9	12.57	Low	48.9	23.06
Seedling	High	July	113.9	20.23	Low	39	39.91
Seedling	High	March	38.8	25.04	Low	29.7	31.76
Seedling	High	July	66.5	29.60	Low	26	40.74
Seedling	High	March	69.7	17.69	Low	52.4	10.36
Seedling	High	July	92.5	13.09	Low	46.1	32.10
Seedling	High	March	47.1	27.24	Low	34.5	22.03
Seedling	High	July	76.8	27.66	Low	47.8	28.82
Seedling	High	March	59.8	15.09	Low	48.3	36.25
Seedling	High	July	100.6	22.68	Low	72.3	25.57
Seedling	High	March	43	10.68	Low	47.5	17.46
Seedling	High	July	60.4	28.47	Low	28	39.12
Potomac	High	March	83	42.30	Low	83.7	29.44
Potomac	High	July	71.3	66.64	Low	46.3	49.81
Wabash	High	March	50.3	19.93	Low	32.2	24.84
Wabash	High	July	58.8	19.30	Low	12.5	27.95
Summer Delight	High	March	48.3	18.72	Low	39.1	35.70
Summer Delight	High	July	65.9	14.98	Low	53.9	33.44
Allegheny	High	March	51.9	16.01	Low	51.9	6.55
Allegheny	High	July	40	36.82	Low	49.3	29.08
KSU Benson	High	March	44.7	3.98	Low	31.2	17.63
KSU Benson	High	July	81.8	11.95	Low	32	30.34
Mango	High	March	36.2	13.05	Low	35.7	6.29

	High	July	54.8	32.80	Low	10.9	24.37
Mango	High	July	54.8	32.80	Low	10.9	24.37
Rappahannock	High	March	43.4	3.73	Low	24.7	18.55
Rappahannock	High	July	46.4	42.49	Low	32.7	45.97

Measurements were taken twice during the growing season. The above chart shows the growth between March and July 2019. Some trees show they are shorter in July; this can be attributed to the tree breaking or death of the graft during the growing season.

Table 5. Piketon Measurement's at 30 cm from Base of Tree.

Cultivar	Input	Sample Date	Mean	Input	Std Dev	Mean	Std Dev
KSU Atwood	High	March	3.698	Low	0.601	4.566	1.174
KSU Atwood	High	July	6.322	Low	4.112	5.055	3.408
Shenandoah	High	March	4.892	Low	1.591	5.882	0.844
Shenandoah	High	July	10.652	Low	5.346	8.116	2.230
Sunflower	High	March	3.374	Low	1.167	3.950	0.412
Sunflower	High	July	6.778	Low	2.237	4.616	2.917
Susquehanna	High	March	4.000	Low	1.488	3.786	0.755
Susquehanna	High	July	12.018	Low	6.408	4.976	2.860
Seedling	High	March	1.790	Low	1.643	3.178	0.825
Seedling	High	July	8.350	Low	5.269	1.516	2.161
Seedling	High	March	2.966	Low	1.287	4.010	1.448
Seedling	High	July	10.286	Low	3.125	3.656	4.126
Seedling	High	March	3.524	Low	0.673	3.684	2.233
Seedling	High	July	10.250	Low	3.424	5.522	3.556
Seedling	High	March	3.308	Low	1.304	4.992	1.995
Seedling	High	July	8.228	Low	4.178	5.128	5.397
Seedling	High	March	2.662	Low	0.751	2.716	1.781
Seedling	High	July	9.162	Low	4.197	3.892	4.570
Seedling	High	March	3.408	Low	2.819	3.756	2.193
Seedling	High	July	10.060	Low	5.021	5.234	2.968
Seedling	High	March	3.014	Low	1.569	5.876	1.905
Seedling	High	July	7.390	Low	6.446	6.626	4.873
KY Champion	High	March	5.372	Low	4.368	3.836	3.775
KY Champion	High	July	6.374	Low	4.928	4.732	4.775
Seedling	High	March	3.114	Low	1.503	4.986	3.266
Seedling	High	July	9.372	Low	7.825	7.790	5.939
Seedling	High	March	2.714	Low	1.003	4.136	1.856
Seedling	High	July	8.514	Low	3.537	1.884	2.655
Seedling	High	March	3.600	Low	0.418	5.216	1.141
Seedling	High	July	14.084	Low	2.566	4.286	4.364

Cultivar	Input		Mean	Input			
Seedling	High	March	3.706	Low	1.481	2.814	1.917
Seedling	High	July	7.474	Low	4.430	2.972	4.071
Seedling	High	March	4.258	Low	0.846	4.592	2.382
Seedling	High	July	11.426	Low	4.265	4.638	3.901
Seedling	High	March	2.398	Low	1.587	2.846	2.266
Seedling	High	July	8.114	Low	4.797	4.772	2.759
Seedling	High	March	3.554	Low	0.495	4.702	3.076
Seedling	High	July	16.078	Low	8.427	7.436	2.804
Seedling	High	March	4.560	Low	3.272	4.580	0.465
Seedling	High	July	7.930	Low	3.990	3.344	4.715
Potomac	High	March	6.988	Low	3.943	5.030	2.370
Potomac	High	July	7.236	Low	6.922	5.156	4.847
Wabash	High	March	5.194	Low	2.352	3.390	2.316
Wabash	High	July	6.920	Low	3.128	1.108	2.478
Summer Delight	High	March	3.954	Low	1.099	3.214	3.226
Summer Delight	High	July	7.500	Low	1.473	5.160	4.202
Allegheny	High	March	3.326	Low	2.142	5.894	1.191
Allegheny	High	July	6.250	Low	6.003	5.908	3.862
KSU Benson	High	March	3.258	Low	1.126	3.324	1.994
KSU Benson	High	July	13.544	Low	2.834	4.182	4.540
Mango	High	March	2.774	Low	0.698	3.876	2.088
Mango	High	July	7.886	Low	5.744	0.902	2.017
Rappahannock	High	March	2.510	Low	0.996	4.206	1.457
Rappahannock	High	July	5.554	Low	5.104	4.040	5.640

Measurements were taken twice during the growing season. The above chart shows the growth between March and July 2019. Some trees show they are smaller in July; this can be attributed to the tree breaking or death of the graft during the growing season.

Table 6. Piketon Measurement's at Base of Tree.

Cultivar	Input	Sample Date	Mean	Std Dev	Input	Mean	Std Dev
KSU Atwood	High	July	10.974	6.424	Low	9.196	5.417
Shenandoah	High	July	21.700	7.873	Low	13.120	3.675
Sunflower	High	July	15.692	4.301	Low	8.158	4.702
Susquehanna	High	July	22.568	7.493	Low	11.484	6.900
Seedling	High	July	12.598	8.270	Low	3.554	5.310
Seedling	High	July	15.068	3.354	Low	7.556	7.950
Seedling	High	July	16.838	3.520	Low	9.524	6.438
Seedling	High	July	18.222	8.720	Low	8.020	8.568
Seedling	High	July	15.174	7.369	Low	6.746	6.335
Seedling	High	July	16.932	5.730	Low	10.466	6.314

Cultivar	Input	Month			Input		
Seedling	High	July	14.288	11.273	Low	12.286	7.670
KY Champion	High	July	12.534	7.203	Low	8.462	8.288
Seedling	High	July	13.602	11.014	Low	9.968	6.092
Seedling	High	July	13.818	4.797	Low	4.102	5.679
Seedling	High	July	20.616	1.961	Low	9.092	8.589
Seedling	High	July	13.332	7.875	Low	4.760	6.701
Seedling	High	July	18.304	2.624	Low	10.028	6.452
Seedling	High	July	16.610	8.597	Low	8.352	4.692
Seedling	High	July	21.572	6.953	Low	10.940	3.542
Seedling	High	July	10.786	5.543	Low	5.872	8.209
Potomac	High	July	12.692	11.901	Low	7.540	7.318
Wabash	High	July	10.802	2.203	Low	1.612	3.605
Summer Delight	High	July	10.324	2.497	Low	7.540	4.704
Allegheny	High	July	13.670	12.535	Low	12.828	7.270
KSU Benson	High	July	21.272	3.935	Low	7.310	7.650
Mango	High	July	13.818	10.881	Low	1.892	4.231
Rappahannock	High	July	10.468	9.719	Low	5.834	7.992

Measurement of the base diameter was taken in July only; the above chart shows the diameter in July 2019.

Table 7. Stand Comparison High and Low Input Piketon 2019.

Cultivar	Input	Percent Survival
Seedling	High	1 A
Seedling	High	1 A
Sunflower	High	1 A
Susquehanna	High	1 A
Shenandoah	Low	1 A
Seedling	High	1 A
Seedling	High	1 A
Seedling	High	1 A
Seedling	High	1 A
Seedling	High	1 A
Seedling	High	1 A
Seedling	Low	1 A
KSU Benson	High	1 A
Seedling	High	1 A
Seedling	High	1 A
Seedling	High	1 A
Seedling	High	1 A
Seedling	Low	1 A
Seedling	Low	1 A

Seedling	High	0.8 AB
Potomac	High	0.8 AB
Seedling	High	0.8 AB
KY Champion	Low	0.8 AB
Seedling	Low	0.8 AB
Seedling	Low	0.8 AB
Shenandoah	High	0.8 AB
Seedling	Low	0.8 AB
KSU Atwood	Low	0.8 AB
Seedling	High	0.8 AB
Mango	High	0.8 AB
Susquehanna	Low	0.8 AB
Wabash	High	0.8 AB
Seedling	Low	0.8 AB
Allegheny	Low	0.8 AB
Seedling	Low	0.8 AB
Seedling	Low	0.8 AB
Potomac	Low	0.6 AB
Seedling	Low	0.6 AB
Seedling	Low	0.6 AB
Allegheny	High	0.6 AB
KSU Atwood	High	0.6 AB
Seedling	Low	0.6 AB
Rappahannock	High	0.6 AB
KY Champion	High	0.6 AB
Summer Delight	High	0.6 AB
Sunflower	Low	0.6 AB
KSU Benson	Low	0.6 AB
Summer Delight	Low	0.6 AB
Seedling	Low	0.4 AB
Wabash	Low	0.4 AB
Seedling	Low	0.4 AB
Seedling	Low	0.4 AB
Rappahannock	Low	0.4 AB
Mango	Low	0.2 B

Table 8. Columbus Growth Measurement's

Cultivar	*Input*	*Height*	*Diameter at 30 cm.*	*Diameter at Base*
Susquehanna	Low	24.63 I	0.358 B	2.4 C
Summer Delight	Low	29.28 HI	0.308 B	2.86 BC
Wabash	High	29.36 GHI	0.282 B	3.76 BC

KSU Benson	Low	32.46 FGHI	0.298 B	6.02 BC
Mango	Low	35.68 EFGHI	0.12 B	9.86 BC
Rappahannock	High	40.79 DEFGHI	0.366 B	8.88 BC
Rappahannock	Low	42.75 CDEFGHI	0.314 B	9.7 BC
Seedling	High	44.6 BCDEFGHI	0.338 B	7.72 BC
Allegheny	High	44.79 BCDEFGHI	0.482 B	13.36 BC
Seedling	Low	45.86 BCDEFGHI	0.318 B	9.74 BC
Seedling	High	46.33 BCDEFGHI	0.428 B	8.76 BC
Seedling	Low	46.44 BCDEFGHI	0.344 B	9.82 BC
KSU Benson	High	48.53 BCDEFGHI	0.366 B	16.82 BC
Mango	High	49.21 BCDEFGHI	7.882 A	14.32 BC
Sunflower	Low	49.94 BCDEFGHI	0.29 B	15.48 BC
Susquehanna	High	50.03 BCDEFGHI	0.486 B	16.78 BC
Sunflower	High	50.33 BCDEFGHI	0.356 B	13.78 BC
Seedling	High	51.44 BCDEFGHI	0.49 B	12.64 BC
Seedling	Low	52.5 ABCDEFGHI	0.392 B	13.44 BC
Seedling	Low	53.23 ABCDEFGHI	0.482 B	11 BC
Seedling	Low	53.52 ABCDEFGHI	0.452 B	10 BC
Seedling	High	53.92 ABCDEFGHI	0.478 B	10.967 BC
Summer Delight	High	54.13 ABCDEFGHI	0.524 B	7.76 BC
Seedling	Low	54.3 ABCDEFGH	0.413 B	12.1 BC
KSU Atwood	High	55.09 ABCDEFGH	0.422 B	9.26 BC
Wabash	Low	56.35 ABCDEFGH	0.47 B	10 BC
Allegheny	Low	56.62 ABCDEFGH	0.598 B	13.92 BC
Potomac	Low	56.75 ABCDEFGH	0.748 B	7.26 BC
Seedling	High	57.7 ABCDEFGH	0.434 B	9.22 BC
Seedling	High	58.12 ABCDEFGH	0.366 B	11.34 BC
Seedling	High	58.19 ABCDEFGH	0.366 B	9.66 BC
Seedling	Low	59.35 ABCDEFG	0.525 B	13.475 BC
Seedling	Low	59.41 ABCDEF	0.502 B	13.06 BC
Seedling	Low	60.5 ABCDEF	0.47 B	14.94 BC
KSU Atwood	Low	60.78 ABCDEF	0.65 B	22.58 B
Shenandoah	High	61.26 ABCDEF	0.598 B	16.68 BC
Seedling	High	62.36 ABCDEF	0.482 B	11.96 BC
Seedling	Low	63.99 ABCDE	0.478 B	13.4 BC
Seedling	High	64.5 ABCDE	0.518 B	10.94 BC
Seedling	High	64.82 ABCDE	0.418 B	12.32 BC
Seedling	Low	64.92 ABCDE	0.5 B	13.62 BC
Seedling	High	65.86 ABCDE	0.468 B	13.55 BC
Seedling	Low	66.49 ABCD	0.498 B	15.32 BC
Seedling	High	67.02 ABCD	0.52 B	10.24 BC
KY Champion	Low	67.04 ABCD	0.534 B	13.3 BC

Cultivar	Input	Mean		
Seedling	Low	69.2 ABCD	0.526 B	13.58 BC
Shenandoah	Low	69.35 ABCD	0.606 B	20.56 BC
Potomac	High	70.43 ABCD	0.442 B	12.04 BC
Seedling	Low	72.26 ABC	0.568 B	15.22 BC
Seedling	High	72.44 ABC	0.636 B	16.44 BC
Seedling	High	72.75 ABC	0.516 B	14.1 BC
KY Champion	High	74.04 AB	0.726 B	13.38 BC
Seedling	High	74.19 AB	0.504 B	47.9 A
Seedling	Low	82.04 A	0.652 B	16.22 BC

All results with the same letter are not significantly different.

Table 9. Columbus Height Measurement's from base.

Cultivar	Input	Sample Date	Mean	Std Dev	Input	Mean	Std Dev
KSU Atwood	High	April	49.820	49.109	Low	68.820	46.688
KSU Atwood	High	July	60.360	38.752	Low	52.740	35.479
Shenandoah	High	April	58.680	5.969	Low	63.260	7.069
Shenandoah	High	July	63.830	3.279	Low	75.430	6.423
Sunflower	High	April	47.800	4.525	Low	39.780	5.259
Sunflower	High	July	52.860	9.573	Low	60.100	12.536
Susquehanna	High	April	47.280	2.700	Low	42.180	8.614
Susquehanna	High	July	52.770	5.820	Low	7.080	10.420
Seedling	High	April	66.760	14.866	Low	58.840	7.314
Seedling	High	July	78.110	15.757	Low	69.130	5.830
Seedling	High	April	56.667	30.609	Low	45.383	36.155
Seedling	High	July	51.167	28.909	Low	63.208	24.239
Seedling	High	April	63.825	37.392	Low	46.650	33.864
Seedling	High	July	67.888	42.089	Low	72.050	20.731
Seedling	High	April	69.400	9.498	Low	68.620	17.959
Seedling	High	July	64.640	21.782	Low	69.770	28.796
Seedling	High	April	44.820	25.354	Low	58.480	17.917
Seedling	High	July	44.380	27.160	Low	71.360	24.988
Seedling	High	April	45.460	26.498	Low	56.220	9.252
Seedling	High	July	47.200	27.718	Low	50.820	11.998
Seedling	High	April	57.380	41.724	Low	78.900	12.353
Seedling	High	July	72.260	29.708	Low	85.170	13.265
KY Champion	High	April	71.480	42.561	Low	59.220	37.122
KY Champion	High	July	76.610	19.496	Low	74.850	24.008
Seedling	High	April	43.480	33.586	Low	38.040	43.991
Seedling	High	July	59.400	30.252	Low	66.960	33.211
Seedling	High	April	68.600	12.634	Low	69.380	26.311
Seedling	High	July	76.900	18.870	Low	75.140	33.197

Cultivar	Input	Date	Mean	Std Dev	Input	Mean	Std Dev
Seedling	High	April	70.080	24.081	Low	43.960	27.961
Seedling	High	July	78.290	19.877	Low	47.750	29.852
Seedling	High	April	63.940	26.755	Low	62.789	21.352
Seedling	High	July	60.770	25.952	Low	56.040	35.087
Seedling	High	April	53.040	35.023	Low	46.860	29.731
Seedling	High	July	62.350	40.278	Low	46.020	30.180
Seedling	High	April	52.600	33.315	Low	48.060	29.621
Seedling	High	July	63.640	23.831	Low	58.400	24.071
Seedling	High	April	66.480	23.615	Low	53.700	13.905
Seedling	High	July	62.530	44.220	Low	67.300	14.709
Seedling	High	April	56.900	21.711	Low	65.860	12.749
Seedling	High	July	59.480	28.210	Low	67.120	26.658
Potomac	High	April	65.900	40.076	Low	74.960	19.002
Potomac	High	July	74.950	22.840	Low	38.540	36.364
Wabash	High	April	33.640	47.130	Low	51.760	49.665
Wabash	High	July	25.080	35.392	Low	60.930	37.006
Summer Delight	High	April	60.160	35.591	Low	42.840	28.034
Summer Delight	High	July	48.100	31.098	Low	15.720	21.659
Allegheny	High	April	42.720	24.355	Low	61.720	10.996
Allegheny	High	July	46.860	18.631	Low	51.520	25.629
KSU Benson	High	April	39.520	2.653	Low	39.820	16.917
KSU Benson	High	July	57.540	7.879	Low	25.100	34.815
Mango	High	April	45.360	8.729	Low	30.200	10.494
Mango	High	July	53.060	7.339	Low	41.150	21.019
Rappahannock	High	April	41.800	2.607	Low	31.340	18.138
Rappahannock	High	July	39.780	22.291	Low	54.160	42.692

Measurements were taken twice during the growing season. The above chart shows the growth between March and July 2019. Some trees show they are shorter in July; this can be attributed to the tree breaking or death of the graft during the growing season.

Table 10.   Columbus Measurement's at 30 cm.

Cultivar	Input	Sample Date	Mean	Std Dev	Input	Mean	Std Dev
KSU Atwood	High	April	0.422	0.393	Low	0.650	0.368
Shenandoah	High	April	0.598	0.060	Low	0.606	0.022
Sunflower	High	April	0.356	0.128	Low	0.290	0.157
Susquehanna	High	April	0.486	0.080	Low	0.358	0.204
Seedling	High	April	0.636	0.197	Low	0.478	0.166
Seedling	High	April	0.478	0.287	Low	0.413	0.321
Seedling	High	April	0.468	0.428	Low	0.525	0.369
Seedling	High	April	0.520	0.103	Low	0.526	0.219

Cultivar	Input	Date			Input		
Seedling	High	April	0.338	0.194	Low	0.500	0.248
Seedling	High	April	0.428	0.286	Low	0.452	0.106
Seedling	High	April	0.418	0.387	Low	0.652	0.247
KY Champion	High	April	0.726	0.411	Low	0.534	0.339
Seedling	High	April	0.490	0.323	Low	0.392	0.418
Seedling	High	April	0.516	0.142	Low	0.568	0.251
Seedling	High	April	0.504	0.254	Low	0.318	0.189
Seedling	High	April	0.482	0.352	Low	0.502	0.301
Seedling	High	April	0.434	0.281	Low	0.344	0.284
Seedling	High	April	0.366	0.234	Low	0.482	0.322
Seedling	High	April	0.518	0.202	Low	0.470	0.209
Seedling	High	April	0.366	0.256	Low	0.498	0.223
Potomac	High	April	0.442	0.365	Low	0.748	0.163
Wabash	High	April	0.282	0.392	Low	0.470	0.459
Summer Delight	High	April	0.524	0.302	Low	0.308	0.281
Allegheny	High	April	0.482	0.290	Low	0.598	0.139
KSU Benson	High	April	0.366	0.072	Low	0.298	0.169
Mango	High	April	7.882	16.837	Low	0.120	0.217
Rappahannock	High	April	0.366	0.054	Low	0.314	0.217

Measurement of the diameter at 30 cm was taken in April only; the above chart shows the diameter in April 2019.

Table 11. Columbus Measurement's at Base of Tree.

Cultivar	Input	Sample Date	Mean	Std Dev	Input	Mean	Std Dev
KSU Atwood	High	July	9.260	5.697	Low	22.580	32.062
Shenandoah	High	July	16.680	1.681	Low	20.560	3.258
Sunflower	High	July	13.780	2.222	Low	15.480	3.112
Susquehanna	High	July	16.780	2.682	Low	2.400	3.950
Seedling	High	July	16.440	3.273	Low	13.400	0.604
Seedling	High	July	10.967	4.235	Low	12.100	4.453
Seedling	High	July	13.550	8.437	Low	13.475	5.061
Seedling	High	July	10.240	3.377	Low	13.580	3.608
Seedling	High	July	7.720	4.957	Low	13.620	5.699
Seedling	High	July	8.760	5.343	Low	10.000	1.378
Seedling	High	July	12.320	4.777	Low	16.220	3.006
KY Champion	High	July	13.380	4.253	Low	13.300	3.941
Seedling	High	July	12.640	5.969	Low	13.440	7.754
Seedling	High	July	14.100	4.821	Low	15.220	5.953
Seedling	High	July	47.900	75.614	Low	9.740	6.671
Seedling	High	July	11.960	3.334	Low	13.060	5.548
Seedling	High	July	9.220	5.421	Low	9.820	6.161

Seedling	High	July	11.340	3.984	Low	11.000	3.797
Seedling	High	July	10.940	7.592	Low	14.940	3.821
Seedling	High	July	9.660	3.627	Low	15.320	7.788
Potomac	High	July	12.040	4.272	Low	7.260	6.650
Wabash	High	July	3.760	5.153	Low	10.000	5.748
Summer Delight	High	July	7.760	4.744	Low	2.860	3.924
Allegheny	High	July	13.360	7.136	Low	13.920	7.661
KSU Benson	High	July	16.820	1.931	Low	6.020	8.346
Mango	High	July	14.320	3.123	Low	9.860	1.629
Rappahannock	High	July	8.880	5.252	Low	9.700	6.981

Measurement of the base diameter was taken in July only; the above chart shows the diameter in July 2019.

Table 12. Stand Comparison High and Low Input Columbus 2018.

Cultivar	Input	Percent Survival
Seedling	Low	1 A
Shenandoah	High	1 A
Sunflower	High	1 A
Susquehanna	High	1 A
Seedling	High	1 A
Seedling	Low	1 A
Seedling	High	1 A
Seedling	Low	1 A
KSU Benson	High	1 A
Mango	High	1 A
Seedling	Low	1 A
Seedling	Low	1 A
Seedling	High	1 A
Seedling	Low	1 A
Susquehanna	Low	1 A
Seedling	Low	1 A
Shenandoah	Low	1 A
Rappahannock	Low	1 A
Allegheny	Low	1 A
Sunflower	Low	1 A
Seedling	Low	1 A
Seedling	High	0.8 AB
Seedling	Low	0.8 AB
Allegheny	High	0.8 AB
Seedling	High	0.8 AB
Seedling	High	0.8 AB
Rappahannock	High	0.8 AB

KY Champion	High	0.8 AB
Potomac	High	0.8 AB
Seedling	Low	0.8 AB
Seedling	High	0.8 AB
Seedling	High	0.8 AB
Seedling	Low	0.8 AB
Seedling	High	0.8 AB
Seedling	Low	0.8 AB
Seedling	Low	0.8 AB
Seedling	Low	0.8 AB
Seedling	High	0.8 AB
Summer Delight	High	0.8 AB
KSU Benson	Low	0.8 AB
Seedling	High	0.8 AB
Seedling	High	0.6 AB
Seedling	High	0.6 AB
Seedling	Low	0.6 AB
mango	Low	0.6 AB
Seedling	High	0.6 AB
KY Champion	Low	0.6 AB
Potomac	Low	0.6 AB
Seedling	High	0.6 AB
Summer Delight	Low	0.6 AB
KSU Atwood	High	0.4 AB
Wabash	Low	0.4 AB
Wabash	Low	0.4 AB
KSU Atwood	Low	0.2 B

Results:

Soil moisture readings were taken in Volume Water Content (VWC), which translates to the percentage of water relative to the soil. Columbus had a few setbacks with the irrigation breaking three times. Piketon had more constant irrigation and this is reflected in the difference between high versus low, which was doubled.

Growth of trees was monitored during the growing season of 2019. Different growth measurements were taken at three different locations on the tree. At the Piketon location, tree height ranged from 90.0 cm (high input seedling) to 22.35 cm in height (low input Wabash). At 30 cm from the base of the tree, measurements ranged from 8.84 cm (high input seedling) to a low of 4.49 cm. (low input seedling). The diameter of the base of the trees ranged from a high of 22.56 cm (high input Susquehanna) to a low of 1.61 cm (low input Wabash). At the Columbus location, tree height ranged from 82.04 cm (low input seedling) to 24.63 cm in height (low input Susquehanna). At 30 cm. from the base of the tree, measurements ranged from 7.88 cm (high input Mango) to a low of .12 cm (low input Mango). The diameter of the base of the trees

ranged from a high of 47.9 cm (high input Seedling) to a low of 2.4 cm (low input Susquehanna). Survival percentage was also measured between treatments. At the Piketon location, 15 high input, and four low input, trees had 100 percent survival. Seven high input, and 10 low input, trees had 80 percent survival; five high input, and seven low input, trees had 60 percent survival; five low input trees had 40 percent survival; and one low input tree had 20 percent survival. At the Columbus location, eight high input, and 13 low input, trees had 100 percent survival. Thirteen trees in high input, and seven in low input, had 80 percent survival; four high input, and five low input, trees had 60 percent survival; one high input, and two low input, trees had 40 percent survival; and one low input tree had 20 percent survival.

Low input trees Piketon orchard.

High input trees Piketon orchard.

High input trees Columbus orchard.

Fruit production varied substantially between sites and years (Table 13). The Across all years the highest yields were recorded at Integration Acres. The vast majority of production there was accounted for by a single, heavily-managed, open-grown stand that received inputs of farmyard manure fertilizer and where there was little competition from other species. Production at the least managed sites (Olentangy Wetlands, Piketon and Waterman Farm) fluctuated substantially from year to year but were particularly low in 2019 (albeit associated with slightly later fruit counts).

Table 13: Total Fruit production at five woodland pawpaw research sites (5-6 plots per site) between 2015 and 2019. Production varies substantially between sites, between plots within sites and between years.

Site	2015	2016	2017	2018	2019
IA		2691	1634	278	422
OI	549	51	277	48	6
Pi		32	327	136	73
RP		383	367	406	243
WA	180	5	271	34	9

Long-term monitoring of woodland pawpaw production revealed a number of important patterns. First, adding the 2018 and 2019 data to existing data collected since 2015 continued to suggest previously-suspected patterns of biennial bearing in pawpaw (Figure 1). Patterns were not consistent between sites but, in general, productivity was much greater in 2018 than in 2019. The harvest in 2019 was lower than anticipated due to a poor spring and dry summer. Fruit count dates were later than ideal which may explain why productivity was so low this year. Indeed, a number of sites showed no evidence of mature fruit.
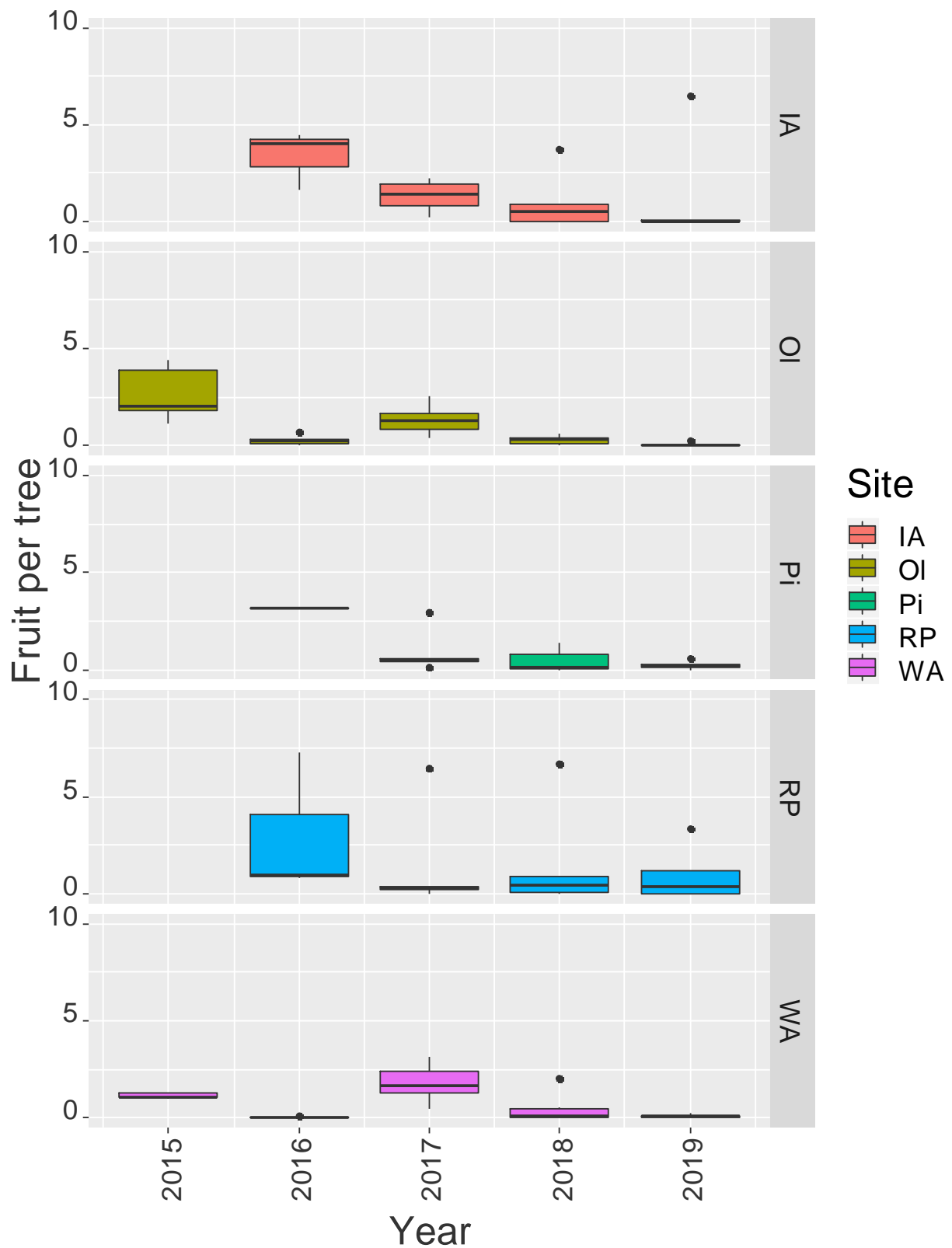
Figure 1: Variation in pawpaw production between 2015 and 2019 at five different monitoring sites in Ohio (IA = Integration Acres; OI = Olentangy Wetlands; Pi = OSU South Centers; RP = Foxpaw Farm; WA = Waterman Farm).

In all years, a substantial number of the trees we evaluated did not produce any fruit and in most plots fruit were associated with a relatively small proportion of productive trees. We analyzed the probability of trees producing fruit as a function of tree size and canopy openness. This demonstrated the significant effect of tree size on fruiting probability – in general trees only had a reasonable probability (> 60%) of producing fruit above ca. 7 cm dbh. There were significant differences in the probability of fruit production between years but not between sites. However, a more open canopy structure (< 50% forest canopy cover) also significantly enhanced the potential for fruiting (Figure 2).
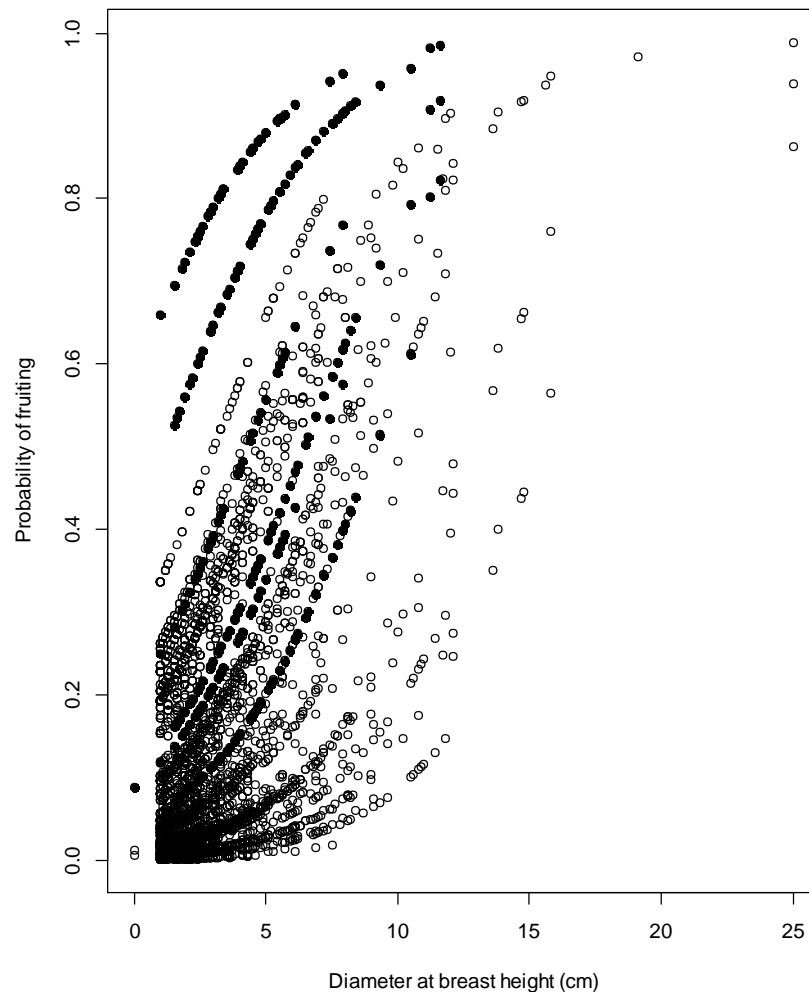

Figure 2: Modeled probability of pawpaw trees producing at least one fruit across five different sites and four years (2015, 2017, 2018, 2019). Fruiting potential increased with tree size up to ca. 10-15 cm at most sites. Plots with open canopies (black circles) had higher probabilities of fruit production

We were not able to detect any effects of woodland management (invasive

removal and thinning on fruit production due to low overall levels of fruiting in 2019 – plots were treated were in sites where we detected very low levels of fruit production. We hypothesize that, if patterns of biennial bearing continue then 2020 should be a productive year and we will see differences between managed and un-managed plots.

Dr. Davies and Brad Bergefurd teaching one of several pawpaw field days and workshops.