Transactions of the Illinois State Academy of Science (2010), Volume 103, #1&2, pp. 1-12
received 10/15/09
accepted 3/20/10

Impact of Selected Cultural Practices on Seedling Growth of Osage Orange (*Maclura pomifera*)

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ABSTRACT

Osage orange (*Maclura pomifera* [Raf.] C.K. Schneid.) is a perennial tree species whose fruit shows potential as a biofuel energy source. However, limited data exists describing the best management practices for seedling production. Research objectives included determining the effects of varying shade percentages on Osage orange seedling growth in a controlled greenhouse environment and the effect from being intercropped with soybean (*Glycine max* L. Merr.) in a field situation. In two separate greenhouse trials, Osage orange seedlings were subjected to a no shade control treatment and shading cloth treatments of 30%, 50%, and 70%. In a field experiment, Osage orange seedlings were intercropped and surrounded by two, one, or no rows of soybeans. In both greenhouse trials, height, fresh and dry leaf weight, dry shoot weight, fresh and dry root weight, and leaf area were significant ($P<0.05$). Fresh shoot weight was also significant in the 120 day greenhouse trial. Generally, height, leaf and shoot weights, and leaf area increased under increasing shade treatments. Contrarily, fresh and dry root weights decreased significantly under increasing shade treatments. In the field trial, Osage orange grown independently or surrounded by one soybean row had significantly ($P<0.05$) higher biomass compared to seedlings intercropped with soybean rows on each side. Although contrary to greenhouse trial results, competition effects such as nutrient and water availability from intercropping in the field, not shading, were likely greater factors in Osage orange seedling biomass. Results show Osage orange can tolerate increased shade without detriment to overall biomass, therefore showing promise for intercropping systems. However, water and nutrient competition should be considered.

Key words: biofuel, *Glycine max*, intercropping, shading, soybean

INTRODUCTION

The need for alternative energy sources has never been more pressing. According to the 2007 Annual Energy Review, energy consumption in the U.S. was 29.9 quadrillion Btu greater than domestic energy production that year. Additionally, the consumption and production of fossil fuels has long outweighed the consumption and production of renewable energy sources. In 2007, fossil fuel usage totaled 86.3 quadrillion Btu while renewable energy accounted for only 6.8 quadrillion Btu of total usage. Similarly, the U.S. produced 49.7 quadrillion Btu more fossil fuel energy than renewable energy (EIA, 2007).

Biofuels show potential to help increase our national energy production from renewable sources. Many biofuel crops, including herbaceous and woody plants, have the potential for production on marginal land not suitable for traditional agricultural crops (Lemus and Lal, 2005), possess the ability to reduce atmospheric carbon through carbon sequestration (Powlson et al., 2005), and can improve soil quality through reduction of erosion and the increase of soil organic carbon (Ma et al., 2000).

Woody tree crops possess all of the aforementioned advantages and preliminary studies show potential from a variety of species including mesquite (*Prosopis* spp. L.), honeylocust (*Gleditsia triacanthos* L.), and persimmon (*Diospyros* spp. L). Another tree not previously studied for biofuel usage is Osage orange (*Maclura pomifera* [Raf.] C.K. Schneid.). Osage orange is a deciduous, hardwood tree, cold hardy to USDA hardiness zones four through nine. Osage orange is a fast growing tree and on average it can grow 2.7 to 3.6 m every three to five years reaching 6 to 12 m in height, with a similar spread (Dirr, 1998). Specifically, the fruit of Osage orange is being investigated for biofuel production due to its high percentage of oil, fermentable sugars, and other carbohydrates (Siebert et al., 1986). Osage orange can begin fruiting at four to six years of age, although fruiting at ten years of age is more common (Dirr, 1998). Siebert et al. (1986) reported preliminary studies that the fruit produced from planting densities of 100 trees per ha could produce 1,073 liters of ethanol per ha. Osage orange is also a long-lived species and it is not uncommon for trees to live to 150 years of age (Smith and Perino, 1981). The fruit can also be harvested without damage to the tree itself. This provides long-term productivity and high fruit yields up to 450 kilograms per tree (Clopton and Roberts, 1949). Osage orange warrants further investigation as a biofuel feedstock due to its extensive distribution, adaptability to a variety of site conditions, disease resistance, high yield potential and numerous by-products (Dirr, 1998; Siebert et al., 1986; Smith and Perino, 1981; Clopton and Roberts, 1949).

Historically used in unmanaged conditions, limited knowledge exists regarding best management practices for Osage orange production in an intercropping system with a cash crop. Since Osage orange does not begin bearing fruit until four to six years of age (Dirr, 1998), there is a need to evaluate the seedling stage of development to determine intercropping suitability. Therefore, the effects of varying shade amounts in a controlled environment and intercropping with soybean in a field situation on Osage orange seedling growth were investigated.

MATERIALS AND METHODS

Experimental Design

The following study consists of two separate investigations. The first was conducted under greenhouse conditions at Illinois State University, Normal, IL (lat. 40° 30’ N). The second was conducted in a field situation at the Illinois State University Horticulture

Center, Normal, IL. Potting mix and soil samples used were tested for physical and chemical properties (Table 1).

Controlled Environment: Shading Trials
The first investigation was conducted using two separate greenhouse trials, beginning in January and July 2008, respectively. For each trial Osage orange seeds (Sheffield's Seed Co., Inc., Locke, NY) were stratified for 30 days at approximately 4°C. Following stratification, seeds were hand sown into four 72-cell plug trays and placed under a mist chamber. The media in which they were grown was BACCTO® Professional Planting Mix (Michigan Peat Co., Houston, TX). After emergence and once seedlings obtained at least two true leaves, they were transplanted into Deepots™ (Hummert Intl., Earth City, MO) tree growing containers. The Deepots™ were suspended in accompanying support trays, placed on greenhouse benches, and covered with shade cloth treatments including a no shade control (0%) and 30%, 50% and 70% shading. Seedlings were hand watered daily or more frequently if required. Daytime temperature was set at 24°C (± 2°C) and nighttime temperature was set at 18°C (± 2°C). Throughout each trial temperature (°C) and light (PAR light; $\mu mol \cdot m^{-2} \cdot s^{-1}$) were monitored. Sensors located next to each group of seedlings recorded temperature and light readings every 10 minutes for the duration of each trial.

Shading Trial 1
For the first trial, 40 Osage orange seedlings were used in each of the four shade treatments. Seedlings were placed in 0.26 liter Deepots™ containers in a completely randomized design with four replications on the greenhouse bench. The trial began in January 2008 and was conducted for 90 days with data collection occurring at 0, 30, 60 and 90 days after transplanting.

Shading Trial 2
For the second trial, 35 Osage orange seedlings were used in each treatment. Seedlings were placed in 0.66 liter Deepots™ containers in a completely randomized design with four replications on the greenhouse bench. The trial began in July 2008 and was conducted for 120 days with data collection occurring at 0, 30, 60, 90 and 120 days after transplanting.

Controlled Environment Data Collection
During each trial, five plants were randomly sampled from each shade treatment at each collection date and destructively harvested. Growth parameters measured included height, number of leaves, fresh and dry weights of the leaves, shoots and roots, and leaf area. Height from the soil level to the terminal stem apex was measured with a ruler, the number of leaves per shoot was counted, and the leaf area was measured using a laser leaf area meter (model CI-203) with conveyor attachment (model CI-203CA; CID, Inc., Camas, WA). Fresh weights were then measured, recorded, and each sample was placed in a drying oven at approximately 75°C for approximately 72 hours to achieve a constant weight. Dry weights of the leaves, shoots and roots were measured and recorded. In shading Trial 2, height of stems and number of leaves were observed and recorded on a weekly basis in addition to previously described data collection.

Field Environment: Intercropping Experiment

An investigation was conducted in the field at the Illinois State University Horticulture Center on a Saybrook silt loam soil (Table 1). A block design with six replications was utilized. The field plot measured approximately 17.5 m by 16.8 m, containing six 3.8 m by 6.1 m blocks, each surrounded by a 1.5 m perimeter (Figure 1). Each block consisted of three rows of ten Osage orange seedlings and three rows of soybean (*Glycine max* L. Merr.) spaced approximately 0.7 m apart (Figure 1). Within row spacing for Osage orange was 61 cm and within row spacing of soybean was 5 cm. This arrangement allowed for each row of Osage orange to be surrounded by two, one or no rows of soybean, respectively. Osage orange seeds were stratified and then hand sown into 128-cell plug trays. After emergence and once seedlings obtained at least two true leaves or reached approximately 6 cm in height, they were directly transplanted into the field plot on June 12, 2008. Soybean seed was also hand sown at this time. Seedlings received supplemental water at transplanting, and then received only natural rainfall throughout the experiment.

Field Environment Data Collection

Data on height and number of leaves were recorded every four weeks for four months. Five Osage orange seedlings were sampled from each row in each of the six blocks and destructively harvested. At experiment completion fresh leaf and shoot weight were recorded. Leaves and shoots were then placed in a drying oven at 75°C for 72 hours. Dry weights of the leaves and shoots were measured and recorded.

Data Analysis

Data were analyzed statistically using the PROC GLM procedure of SAS (Ver. 9.1; Cary, NC). Least squared means for height, number of leaves, fresh and dry leaf, shoot, and root weights, and leaf area were separated statistically. Means values were considered statistically different between treatments at $P \leq 0.05$.

RESULTS AND DISCUSSION

Controlled Environment: Shading Trials

Mean values of Osage orange seedling growth parameters from the greenhouse controlled environment Trials 1 and 2 are listed in Table 2 and Table 3, respectively.

Height was shown to be a significant factor ($P \leq 0.05$) between shading treatments in both shading trials. At completion of 90 days in Trial 1, all shaded Osage orange seedlings were significantly taller than seedlings exposed to less or no shade. For example, mean height for seedlings shaded at 70% was 239.8 mm per plant, compared to 144.5 mm per plant for seedlings exposed to no shade. Results were similar in shading Trial 2, as unshaded control seedlings were significantly shorter ($P \leq 0.05$) at 230.8 mm per plant compared to 281.8 mm, 348.0 mm, and 343.6 mm per plant for seedlings exposed to 30%, 50%, and 70% shade, respectively. Groninger et al. (1996) reported stem height for both Red maple (*Acer rubrum* L.) and Yellow poplar (*Liriodendron tulipifera* L.) increased when exposed to an 89% shade treatment compared to 79% shade or full sunlight. Similarly, when grown under 79% or 89% shade, Sessile oak (*Quercus petraea* (Mattuschka) Liebl.), English oak (*Quercus robur* L.), and Overcup oak (*Quercus lyrat*a Walter) seedlings showed greater total height (Cardillo and Bernal, 2006).

While mean number of leaves was a significant factor over time as seedlings grew in both trials, it was not shown to be significantly different among treatments. Results are supported by Cardillo and Bernal (2006), who found no significant difference in number of leaves between diminishing light treatments at 90 days, and only small increases between 90 and 120 days. This finding suggests that number of leaves per plant is not a growth parameter that is significantly affected by changes in light environment.

Both fresh leaf weight (FLW) and dry leaf weight (DLW) were shown to be significantly greater ($P \leq 0.05$) in seedlings exposed to increased shade in both trials (Tables 2 & 3). In Trial 1, mean FLW was 2.51 grams (g) per plant and mean DLW was 0.56 g per plant under 70% shade, while unshaded control seedlings weighed 1.69 g and 0.49 g per plant for mean FLW and DLW, respectively. Results were similar in Trial 2 as mean leaf weights increased significantly in seedlings treated with heavier shade.

Fresh shoot weight (FSW) was also significant among treatments in each shading trial. Mean FSW was significantly greater ($P \leq 0.05$) among seedlings exposed to greater percentages of shade. Mean FSW were 0.96 g per plant for 70% shade and 0.67 g per plant for 0% shade, as illustrated in trial 1, and 1.35 g per plant for 70% shade compared to 1.06 g per plant for 0% shade, as illustrated in Trial 2 (Tables 2 & 3).

While mean FSW were significant between treatments in both greenhouse trials, mean dry shoot weight (DSW) was only significant ($P \leq 0.05$) in the Trial 2 (Table 3). Results for mean DSW followed those of mean FSW in that more heavily shaded seedlings possessed greater weights. For example, unshaded seedlings had mean DSW of 0.48 g per plant, which was significantly less ($P \leq 0.05$) than 0.50 g, 0.61 g, and 0.59 g per plant when exposed to 30%, 50%, and 70% shading, respectively.

At completion of each shading trail, significant differences in seedling leaf area were also shown. Leaf area in Trial 1 was significantly higher ($P \leq 0.05$) at 166.2 cm^2 per plant under 70% shade, compared to 107.7 cm^2, 146.1 cm^2, 96.3 cm^2 per plant in 50%, 30%, and 0% shade, respectively. Trial 2 demonstrated equally strong results as there was significantly higher leaf area in seedlings exposed to 70% shade with 286.6 cm^2 per plant. Comparatively, leaf area was only 275.8 cm^2, 248.7 cm^2, and 178.1 cm^2 per plant, when treated with 50%, 30%, and 0% shade, respectively (Table 3). These results are supported by studies done by Cardillo and Bernal (2006), where seedlings grown under diminished light had significantly higher leaf areas, and Groninger et al. (1996), in which leaf area in open-grown seedlings was significantly lower than those grown in shade. Loach (1970) reported that high leaf area under low irradiances may allow seedlings to harvest light more effectively and explains how seedlings adapt to low light environments.

Above ground biomass increases are supported by previous studies. For example, King (2003) reported Striped maple (*Acer pennsylvanicum* L.) and American chestnut (*Castanea dentata* (Marsh.) Borkh.) had substantial differences in the allocation of above-ground and below-ground biomass when comparing shade-grown and sun-grown saplings. Specifically, above-ground biomass increased in shaded saplings, most of which was allocated to the leaves (King, 2003). This finding corresponds to mean leaf and shoot weights recorded during both shading trials, as leaf weights were generally higher than shoot weights under similar treatments. It can be inferred from these findings that Osage orange will tolerate increasing shade without detriment to above-ground seedling biomass.

Contrary to above-ground growth parameters discussed, fresh root weight (FRW) and dry root weight (DRW) were significantly greater in unshaded control seedlings. For example, in shading Trial 1, mean FRW was 4.48 g per plant in the unshaded control, which was significantly greater ($P \leq 0.05$) than 3.97 g and 2.67 g per plant when exposed to 50% and 70% shade, respectively (Table 2). In Trial 2, mean FRW was also significantly greater ($P \leq 0.05$) when seedlings were exposed to no shade (Table 2). Unshaded seedlings had mean FRW of 5.89 g per plant, which were significantly higher than seedlings exposed to 30%, 50%, and 70% shade, weighing 4.87 g, 4.57 g, and 4.56 g per plant, respectively (Table 3). Mean DRW exhibited similar results to FRW. These results coincide with studies by Callaway (1992) who reported Valley oak (*Quercus lobata* Née) and Blue oak (*Quercus douglasii* Hook. & Arn.) exhibited large decreases in root mass when exposed to greater shade. Decreased root mass in seedlings exposed to increased shade is a result of greater energy allocation to above-ground biomass. Neufeld (1983) reported that a plants root system is more responsive to lower light levels and shade adaptation is accomplished at the expense of the root system.

Generally, treating Osage orange seedlings with increased shade resulted in increased growth and above-ground biomass, while decreasing below-ground biomass. This corresponds with work done by Retana et al. (1999) who reported Holm oak (*Quercus ilex* L.) showed better growth and increased survival in more shaded seedlings, especially in cases of reduced water availability. According to Canham et al. (1990), the morphological and physiological adaptations that allow improved growth in poor light conditions offer competitive advantage.

Field Environment: Intercropping Experiment

Overall, intercropping Osage orange with soybean tended to decrease plant growth in Osage orange (Table 4). For example, mean FLW of Osage orange grown with soybean on each side was 7.6 g per plant, which was significantly less ($P \leq 0.05$) than 10.4 g per plant when grown next to only one row of soybean. Similarly, mean FSW was significantly less ($P \leq 0.05$) when Osage orange was grown with soybean on both sides compared to only one side or when grown independently. Mean FSW was 5.72 g per plant when heavily intercropped versus 9.33 g and 9.32 g per plant, respectively, when grown both with soybean on one side and independently. Likewise, mean dry weights of Osage orange were significantly less ($P \leq 0.05$) when heavily intercropped with soybean (Table 4). These results coincide with Ssekabembe (1985) who reported higher Leucaena (*Leucaena* spp. Benth.) yields when wider alley spacings were utilized.

Mean plant heights and number of leaves were significantly different among treatments (Table 5). Mean plant height of Osage orange differed significantly ($P \leq 0.05$) among row treatments, with heavily intercropped trees being significantly shorter at 21.6 mm compared to trees intercropped on one side and grown independently at 22.2 mm and 27.1 mm, respectively. Likewise, mean number of leaves per plant was also significantly different among the three treatments. When intercropped with soybean on both sides, number of leaves per Osage orange plant decreased significantly ($P \leq 0.05$) to 43.9 leaves per plant from 65.1 and 51.9 leaves per plant, respectively, when grown with soybean on one side or independently.

It is important to note in this field experiment that replications were shown to be significantly different ($P \leq 0.05$), as indicated in Table 4 and Table 5. Significant replications were likely caused by row edge effects within the experiment plot. Generally, experimental data showed less overall plant mass and lower heights for Osage orange seedlings grown in the third row, or northern facing edge, of blocks three and six (Figure 1). Similarly, the first Osage orange seedlings grown in each row of blocks one, two, and three, or the western facing edge, tended to have less overall plant mass and lower heights than Osage orange seedlings grown further within each row of these blocks (data not shown).

Although results from the field trial are somewhat contradictory to results obtained in the greenhouse trials, decreased biomass in Osage orange seedlings which were heavily intercropped is more likely a factor of competition for nutrients and water and not directly due to shading. Ssekabembe (1985) discussed trees that have large portions of their root systems in the surface soil, especially before the tap root system can be developed, are more likely to be in competition for nutrients and water, rather than aboveground competition for light. This finding applies to the field experiment as the Osage orange seedlings were not likely to have fully developed their root systems before experiment completion.

CONCLUSION

Based upon results obtained from both the greenhouse controlled environment shading trials and the field intercropping experiment, it can be reasoned that Osage orange seedlings will tolerate increased shade amounts without detriment to overall biomass. However, when intercropped heavily, Osage orange seedling biomass will likely decrease due to nutrient and water competition because of its immature root system. From these findings, producers using Osage orange for biofuel production within an intercropping system of crops such as soybean should account for competitive crop effects with adequate row spacings, in addition to shading, in order to maximize growth and biomass amounts.

ACKNOWLDEGMENTS

This project was funded by a grant from the Illinois Council on Food and Agricultural Research (C-FAR) and supported by the Illinois State University (ISU) Department of Agriculture. It partially fulfilled the requirement for an M.S. degree for Jenna Rozum. The authors would also like to thank Jessica Chambers, ISU Horticulture Center Coordinator, Tyler Harvey, and Mike Busing for their assistance.

Figure 1. Arrangement of each experimental block in the field plot (A) and arrangement of soybean (*Glycine max*) and Osage orange (*Maclura pomifera*) in each of the six blocks (B) on a Saybrook silt loam at the Illinois State University Horticulture Center, Normal, IL.

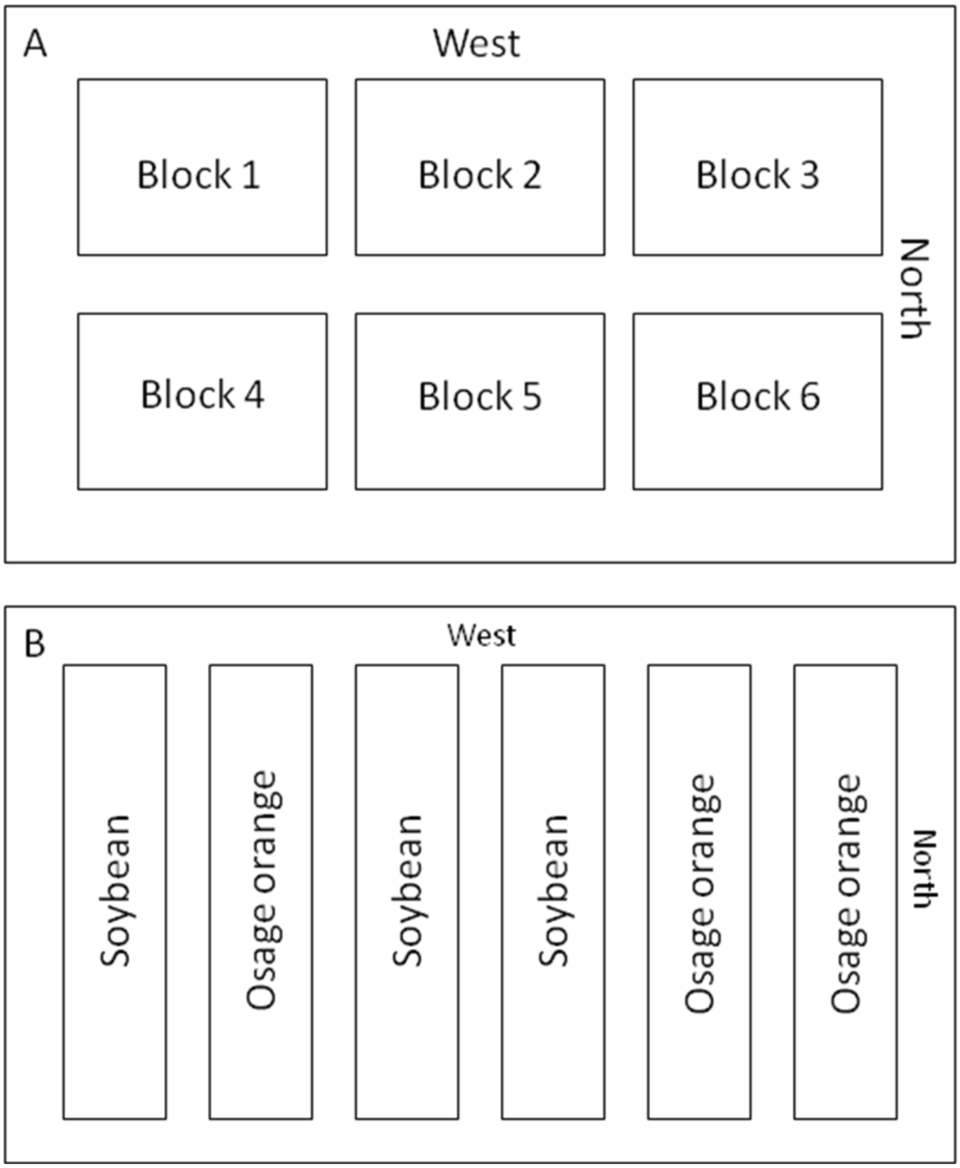

Table 1. Physical and chemical properties of potting mix and field soil used to determine the effects of shading and intercropping on Osage orange (*Maclura pomifera*) seedling development[z].

	Texture Class Percentage								Pounds per acre				Percent saturation				CEC[y]
	Sand	Silt	Clay	Peat	Perlite	Water pH	Buffer pH	OM%	P	K	Ca	Mg	Ca	Mg	K	H	meq/100g
BACCTO® potting mix	–	–	–	80-90	20-10	5.8	6.3	5	170	1238	1970	2336	22.9	46.1	7.2	23.9	21.5
Saybrook Silt Loam	17.1	52.7	30.2	–	–	6.2	6.7	4	54	394	4250	878	60.4	20.6	2.8	15.3	17.6

[z] Values are averages of three samples.
[y] CEC=Cation exchange capacity.

Table 2. Mean values[z] of Osage orange (*Maclura pomifera*) seedling growth parameters after 90 days in greenhouse Trial 1.

	0% Shade				30% Shade				50% Shade				70% Shade					P > F		
Time[y]	0	30	60	90	0	30	60	90	0	30	60	90	0	30	60	90	SEM[u]	Time	Trt	Time*Trt
Height[x]	89.8	138.2	99.8	144.5	93.4	97.5	147.3	237.3	64.6	131.0	121.4	172.5	86.0	138.0	150.0	239.8	13.325	<.0001	0.0020	0.0019
Number of Leaves	6.4	13.0	10.6	16.4	6.0	9.0	12.0	18.0	4.6	11.8	8.6	16.4	5.2	11.2	11.2	19.3	1.170	<.0001	0.3653	0.2510
FLW[w]	0.38	1.11	0.89	1.69	0.40	0.74	1.42	2.30	0.20	0.86	0.83	1.85	0.32	0.99	1.17	2.51	0.179	<.0001	0.0477	0.1441
DLW[w]	0.14	0.30	0.30	0.49	0.14	0.22	0.43	0.40	0.09	0.24	0.25	0.47	0.10	0.20	0.29	0.56	0.049	<.0001	0.0639	0.3823
FSW[w]	0.18	0.48	0.21	0.67	0.16	0.25	0.43	0.88	0.12	0.29	0.28	0.62	0.10	0.32	0.48	0.96	0.085	<.0001	0.1405	0.1168
DSW[w]	0.07	0.10	0.08	0.25	0.07	0.40	0.15	0.32	0.05	0.08	0.10	0.19	0.05	0.08	0.15	0.21	0.063	0.0009	0.0271	0.3170
FRW[w]	0.62	1.79	1.71	4.48	0.78	1.62	2.89	4.60	0.54	1.48	1.68	3.97	0.66	1.49	1.43	2.67	0.363	<.0001	0.0089	0.1358
DRW[w]	0.13	0.37	0.43	1.29	0.17	0.35	0.73	1.34	0.14	0.25	0.40	1.03	0.15	0.29	0.40	0.65	0.098	<.0001	0.0017	0.0193
CDW[w]	0.34	0.78	0.70	2.03	0.38	1.09	1.30	2.29	0.28	0.57	0.76	1.68	0.30	0.57	0.84	1.31	2.013	0.2201	0.1288	0.2394
Leaf Area[v]	24.8	66.5	50.1	96.3	28.3	46.97	70.6	146.1	18.4	58.3	48.2	107.7	17.9	66.3	67.9	166.2	9.820	<.0001	0.0084	0.0093

[z] Values are means of 5 plants.
[y] Days from transplanting.
[x] Height measured in millimeters (mm) from soil level to shoot apex.
[w] Weights measured in grams (g). Abbreviations FLW=fresh leaf weight; DLW=dry leaf weight; FSW=fresh shoot weight; DSW=dry shoot weight; FRW=fresh root weight; DRW=dry root weight; CDW=cumulative dry weight.
[v] Leaf area measured in squared centimeters (cm^2).
[u] SEM=Standard error of the mean.

Table 3. Mean values[z] of Osage orange (*Maclura pomifera*) seedling growth parameters after 120 days in greenhouse Trial 2.

	0% Shade					30% Shade					50% Shade					70% Shade						P > F		
Time[y]	0	30	60	90	120	0	30	60	90	120	0	30	60	90	120	0	30	60	90	120	SEM[u]	Time	Trt	Time*Trt
Height[x]	158.2	210.8	195.2	213.2	230.8	145.6	236.4	245.6	256.8	281.8	167.8	252.4	280.0	303.0	348.0	162.2	234.2	269.4	291.2	343.6	14.01	<.0001	<.0001	0.0132
Number of Leaves	12.0	20.0	19.2	19.6	24.4	10.0	18.4	23.0	23.8	25.6	11.4	19.0	26.8	28.8	28.0	12.4	17.4	23.6	21.2	28.0	2.479	<.0001	0.1168	0.6762
FLW[w]	0.93	2.39	1.92	2.29	3.40	0.63	2.01	2.63	2.74	4.36	1.09	2.62	3.59	3.97	4.39	1.01	1.87	2.51	3.13	4.14	0.318	<.0001	0.0003	0.2686
DLW[w]	0.24	0.66	0.56	0.65	1.06	0.17	0.56	0.72	0.75	1.26	0.27	0.62	0.85	1.03	1.26	0.26	0.44	0.75	0.78	1.14	0.086	<.0001	0.0134	0.3073
FSW[w]	0.25	0.77	0.58	0.92	1.06	0.280	0.71	0.95	1.09	1.18	0.36	0.61	0.94	1.29	1.37	0.36	0.64	0.91	1.01	1.35	0.097	<.0001	0.0173	0.1935
DSW[w]	0.09	0.27	0.22	0.36	0.48	0.07	0.25	0.36	0.42	0.50	0.11	0.26	0.38	0.48	0.61	0.11	0.20	0.31	0.39	0.59	0.035	<.0001	0.0048	0.1371
FRW[w]	1.83	2.62	3.66	5.25	5.89	1.09	2.61	3.78	4.58	4.87	2.15	2.90	3.25	4.41	4.57	1.91	2.18	3.01	3.13	4.56	0.413	<.0001	0.0119	0.1928
DRW[w]	0.30	0.71	0.93	1.28	2.04	0.18	0.69	0.97	1.36	1.49	0.33	0.69	0.97	1.26	1.50	0.26	0.46	0.67	0.80	1.40	0.118	<.0001	0.0003	0.1038
CDW[w]	0.63	1.64	1.71	2.29	3.58	0.41	1.49	2.06	2.53	3.25	0.71	1.49	2.10	2.77	3.37	0.63	1.10	1.73	1.97	3.13	0.199	<.0001	0.0274	0.5489
Leaf Area[v]	53.9	114.2	149.0	151.3	178.1	40.4	98.6	214.3	146.0	248.7	58.8	169.8	274.2	251.4	275.8	56.9	108.9	289.3	218.4	286.6	21.73	<.0001	<.0001	0.0331

[z] Values are means of 5 plants.
[y] Days from transplanting.
[x] Height measured in millimeters (mm) from soil level to shoot apex.
[w] Weights measured in grams (g). Abbreviations FLW=fresh leaf weight; DLW=dry leaf weight; FSW=fresh shoot weight; DSW=dry shoot weight; FRW=fresh root weight; DRW=dry root weight; CDW=cumulative dry weight.
[v] Leaf area measured in squared centimeters (cm^2).
[u] SEM=Standard error of the mean.

Table 4. Mean values[z] of Osage orange (*Maclura pomifera*) seedling growth parameters when intercropped with three treatments of soybean (*Glycine max*) grown on a Saybrook silt loam soil under field conditions.

	Osage Orange Row[y]				P > F	
	Row 1[x]	Row 2[w]	Row 3[v]	SEM[u]	Trt	Rep
FLW[t]	7.60	10.36	9.72	0.786	0.0386	0.0390
DLW	4.03	6.56	6.43	0.600	0.0066	0.0227
FSW	5.72	9.33	9.32	0.988	0.0147	0.0007
DSW	4.54	7.22	7.05	0.751	0.0224	0.0121

[z] Values are means of 5 plants.
[y] Weights are measured in grams (g).
[x] Osage orange seedlings surrounded by soybean on each side.
[w] Osage orange seedlings surrounded by soybean on one side.
[v] Osage orange seedlings surrounded by no soybean.
[u] SEM=Standard error of the mean.
[t] Abbreviations FLW=fresh leaf weight; DLW=dry leaf weight; FSW=fresh shoot weight; DSW=dry shoot weight.

Table 5. Mean values[z] of Osage orange (*Maclura pomifera*) seedling height and number of leaves when intercropped with three treatments of soybean (*Glycine max*) grown on a Saybrook silt loam soil under field conditions.

	Row 1[w]					Row 2[v]					Row 3[u]						P > F			
Time[y]	0	30	60	90	120	0	30	60	90	120	0	30	60	90	120	SEM[t]	Time	Trt	Rep	Time*Trt
Height[x]	2.6	8.4	14.4	19.3	21.6	2.6	8.8	15.2	19.9	22.2	2.6	10.9	18.1	23.9	27.1	0.906	< .0001	< .0001	< .0001	0.1023
Number of Leaves	3.1	15.4	26.8	36.6	43.9	3.2	18.5	32.2	43.2	51.9	3.2	25.0	41.2	54.1	65.1	2.587	< .0001	< .0001	< .0001	0.0093

[z] Values are means of 5 plants.
[y] Days from transplanting.
[x] Height measured in millimeters (mm) from soil level to shoot apex.
[w] Osage orange seedlings surrounded by soybean on each side.
[v] Osage orange seedlings surrounded by soybean on one side.
[u] Osage orange seedlings surrounded by no soybean.
[t] SEM=Standard error of the mean.

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