The Three Sisters are corn, beans, and squash, which are planted together as crop companions in traditional Native American agriculture. [1] According to Iroquois legend, the Creator gave these crops to the Iroquois people, intending them to be raised together as three sisters who thrive in community. Three Sisters agriculture has been practiced in native societies from Mesoamerica to the Great Plains and eastward to the Atlantic. [2] These three crops are not only grown together, but also eaten together to create a complete diet. Corn serves as the carbohydrate base, beans provide the necessary protein lacking in corn, and squash provides vitamins and oil. [3]
The crops are traditionally planted in mounds, with a cluster of corn plants in the center and pole beans around the circumference. This allows the beans to climb up the corn stalks like a trellis. Squash are planted in between the mounds of corn and beans, given ample room to vine out and cover the ground. The vining squash acts as a living mulch, shading the ground to inhibit weed growth and conserve soil moisture. The architecture of the Three Sisters also purportedly limits insect pest pressure by confusing pests and attracting the beneficial insect predators that will keep the pest populations in check. This polyculture produces abundantly while leaving a light footprint on the land, as each of the crops has different nutritional needs and the beans are able to fix nitrogen that is available the following year. [4]

We decided to conduct a trial of the Three Sisters at the Kerr Center in order to assess the potential of this planting scheme for market farmers and gardeners. The purported benefits of this planting design were more than enough to pique our interests and fit well into our goal of designing resilient systems for organic production. We decided to plant open-pollinated or heirloom varieties so that we could also assess the performance of the cultivars themselves. We chose flour corn, pole beans, winter squash, and pumpkins because all of these crops could be harvested at full maturity, limiting our need to enter the field mid-season. Specific varieties were chosen based upon their adaption to the Southern climate and characteristics that made them appear well-suited for the Three Sisters system. The following varieties were chosen:

- **Flour Corn**: Texas Gourdseed
- **Pole Beans**: Kentucky Wonder, Hidatsa Shield Figure, True Red Cranberry, Turkey Craw
- **Winter Squash**: Waltham Butternut, Table Queen Acorn
- **Pumpkins**: Seminole, Cinderella

We changed the traditional mound-planted, checkered pattern into a row-planted design to fit our scale of production and available equipment. This required some improvisation and estimation on plant spacing. We decided to plant mid-summer for a fall harvest in order to avoid peak summer temperatures when our crops would be in their reproductive phase. This decision was based on prior experience with the 2011 Flour Corn Trial and a limited harvest due to extreme summer temperatures. We also planned to establish the Three Sisters with minimal tillage, only strip-tilling the rows where corn would be planted. The intent was to leave a layer of cover crop residue on the surface of the soil to suppress weed growth between the rows of corn.

**Location and Methods**

The Three Sisters Trial was located at the Cannon Horticulture Project site on the Kerr Center Ranch. The Horticulture Project was established in the fall of 2007 and achieved certified organic status in June 2011. The Cannon site features a loam soil with moderately-poor drainage, organic matter levels around 3.1%, and a pH that ranges from 6.6 to 7.0. While native phosphorus and potassium levels on these soils are low, compost applications in 2009 improved the phosphorus status considerably and moderately improved the levels of potassium.

In 2011 the field had been planted to a summer cover crop of sorghum-Sudangrass, Sudangrass, and buckwheat, followed by a winter cover crop of grain rye, crimson clover, purple vetch, and tillage radish. Before the Three Sisters were planted in 2012, we established a summer cover crop of Viking Soybeans to provide for some of the nitrogen needs of the corn and squash. The soybeans were planted in the spring after the winter cover crops had been mowed and disked into the soil. The soybeans
were grown until pod set, but mowed with a sickle bar mower on June 21 before seeds became mature.

The Three Sisters field plot measured 45 feet wide by 280 feet long. The design featured eight rows of corn that stretched the length of the field with five feet between rows. The beans were planted in the rows, between the corn plants, with squash planted in the inter-row space between the corn and bean rows.

After the soybean cover crop was mowed, on June 25, we used a hay rake to sweep the soybean residue out of the rows where corn would be planted. The soil was very dry at this point, so we laid down drip tape in the eight rows and irrigated for three hours the day before strip tilling. On June 28, the rows were strip-tilled in six-inch bands with a BCS roto-tiller modified so that only the two sets of middle tines remained. An organic fertilizer blend with a 1.7-3.4-3.5 analysis was applied to the strip-tilled rows at a rate of 93 pounds per acre or 1.5-3.2-3.3 pounds of N-P-K per acre. The rows were strip-tilled again to incorporate the fertilizer.

We planted the corn with a Jang Precision Seeder following fertilization. Final seeding was completed on July 6, and thinned to one plant per foot on July 17. We laid down drip tape between the corn rows on July 18 to prepare for seeding the squash. The squash rows received two hours of drip irrigation before we hand-planted the squash seed with a jab planter, three seeds per hill with hills spaced six feet apart. Beans were also planted on the 18, using jab planters to plant two seeds between every two corn plants in the row. Seeding began late in the afternoon of July 18 and was finished in the following morning, with two hours of drip irrigation following.

**Weed Control**

Despite the fact that we desired to maintain the Three Sisters trial as a minimal-till system, we experienced a weed flush of amaranth in mid-July that necessitated cultivation. Because we had left the soybean cover crop residue on the surface as a dry mulch, we couldn’t use wheel hoes or hand hoes effectively to control the weed flush. Our only option left was to till between the rows to control the weed seedlings. We had hoped that leaving the cut soybean residue on the surface of the soil and only strip-tilling in the corn rows would prevent new weeds.
from emerging, but that was not the case. We used the modified BCS roto-tiller to till a narrow band of soil between the corn and squash rows, which buried both the weed seedlings and some of the soybean mulch. Subsequent weed control was accomplished by picking off stray weeds with a long-handled hoe periodically throughout the season.

**Weather**

The summer of 2012 was a scorcher. By late June we were already seeing temperatures reach above 100°F, and we continued to see temperatures in that range until mid-September. We received periodic rains at two to four inches a month from June to September, but that was not enough to keep moisture in the soil. The plants were very stressed by both heat and drought. Drip irrigation provided the soil moisture the crops needed to survive.

**Insect Pest Control**

Insect pests were especially difficult during the 2012 growing season. We spotted fall armyworms (Spodoptera frugiperda) on the corn in late July. By that time they had already caused noticeable damage to the inner whorl of leaves, necessitating control measures. On July 27 we sprayed a mixture of Bacillus thuringiensis var. kurstaki (Btk), liquid fish and seaweed, effective microorganisms, and molasses to provide both insect control and a nutritional boost to the young corn plants. A further application of Btk plus effective microorganisms and molasses was made on July 30 after more armyworms were observed on corn foliage.

Grasshoppers became a big problem by the end of July, effectively destroying all bean seedlings by mid-August. The beans were not able to recover from the severe damage they suffered from swarms of grasshoppers and we saw no survival in any of the varieties. The grasshoppers also fed on squash seedlings, which, combined with the extreme summer temperatures, took a toll on squash survival. By August 6 only 32% of the acorn and 80% of the butternut squash had survived. The two pumpkin varieties had a much better survival rate. 87% of the Seminole and 99% of the Cinderella pumpkin that were planted germinated and survived the first three weeks.
After we first spotted squash bugs (Anasa tristis) on August 8, we began to hand-pick the squash bugs and eggs off the leaves of the squash and pumpkins in the trial. This was done weekly, which kept the population in check, but did not provide 100% control. Most of the pressure was on the Cinderella pumpkin, with fewer squash bugs found on the butternut and acorn squash. The Seminole pumpkin had very few squash bugs.

Damage from squash vine borers (Melitta cucurbitae) began to appear in mid-August. All four squash and pumpkin varieties experienced damage from the vine borer, though it was especially devastating for the Cinderella pumpkin; more than half of the plants were lost. We tried to control the insect pest by cutting open infested stems and removing the larvae, but the larvae were very difficult to find without severely damaging the plant. We hilled soil up around the stems of uninfested plants to prevent the parent moth from laying eggs on the stems of our cucurbits, but this measure did not prevent further damage.

The most severe insect pest in the trial was the spotted cucumber beetle (Diabrotica undecimpunctata howardi), which appeared on the squash and pumpkins in late August. This insect is also known as the southern corn rootworm because its larvae feed on corn roots. The severity of pressure from the cucumber beetle was likely caused by both the larvae and adults having access to their preferred food sources in the same area. The pressure from cucumber beetles necessitated regular spot-spray applications of Pyganic® (pyrethrin) and neem oil, once or twice a week from late August to early October. The beetles congregate in squash and pumpkin.
blossoms early in the morning, so early morning applications were made to avoid harming bee populations. The Pyganic® and neem combination proved effective, but the beetle infestation returned several days later. The Cinderella pumpkin was especially damaged, with the acorn and butternut squash suffering less, but still significantly. The Seminole pumpkin did not receive much pressure from the beetles until late-September, after it began to set fruit.

Also very low. A hard freeze hit on October 29, which necessitated an early pumpkin harvest. Cinderella was a crop failure, only producing two pumpkins. Seminole yielded 176 pounds of fruit from 490 row feet, most of which were immature due to the early harvest.

The corn was harvested by hand on November 15, after the stalks had dried down. The ears were shucked in the field then brought indoors for further drying. Corn smut, corn earworm damage, and ear rot lowered the number of harvestable ears. After the ears were dried and shelled, we ended up with 150 pounds of flour corn.

Despite the unfavorable weather and pest pressure, we were able to harvest squash, pumpkins, and corn, but not beans. The butternut and acorn squash were harvested by hand on October 24, 98 days after planting. Table Queen Acorn yielded 34 pounds of marketable fruit from 490 row feet, which was a very low yield compared to market standards. Waltham Butternut yielded about 81 pounds of marketable fruit from 490 row feet, which was also very low.
Discussion

We encountered several unanticipated difficulties in implementing the Three Sisters trial at the Kerr Center. In some cases, the purported benefits of the Three Sisters did not hold true for us, and in other cases, our management decisions created hardships. Despite the difficulties we faced in this trial, we believe there are reasons to continue to explore the Three Sisters system as a means to produce corn, beans, and squash.

Insect Pests

We dealt with many insect pests that caused significant damage to the beans, squash, and pumpkins. Grasshoppers had no problem finding tender bean seedlings between corn plants, eliminating the crop from our planting. The most damaging pest to the squash and pumpkins was the spotted cucumber beetle, which is also a corn pest in the form of the southern corn rootworm. Instead of confusing pests through polyculture, the corn, squash, and pumpkins actually provided the perfect habitat for pests like the cucumber beetle. The design of the planting also made it difficult to get in the field for pest control and scouting. In order to walk down the rows, we had to step over the sprawling vines of the squash and pumpkins, inadvertently damaging plants. In the case of pest control, the polyculture of the Three Sisters ended up working against us.

Timing

We had decided on a late planting date in an attempt to avoid pollination during peak summer temperatures. The late planting date allowed the corn to tassel during more favorable temperatures, but it created difficulties for our seedlings trying to grow in mid-summer. Bean, squash, and pumpkin seedlings had to put on initial growth in temperatures that reached above 100°F. They were also exposed to peak populations of summer pests at a time in their development when they were most vulnerable. These stresses on the plants led to the loss of our beans and a serious reduction in squash yield.

We are interested in observing how the Three Sisters would perform if they were planted earlier in the growing season. An early planting would allow the crops to be in a more mature growth stage before the stresses of summer hit in full force. If our beans had been mature in July they might have withstood grasshopper damage without it causing crop failure. Cooler temperatures would also help the squash or pumpkins vine out between the corn rows, casting shade on the ground before the summer sun begins to beat down on the soil with a vengeance. A field overgrown with bean and squash vines might confuse some insect pests, but the question remains which insects would take advantage of the design. Obviously the cucumber beetle is...
able to exploit the corn and squash polyculture, which would likely be a problem even in a spring planted Three Sisters.

Polyculture Design

Because of the stresses on our crops, the Three Sisters did not grow into its full architectural potential. We did not have pole beans to trellis up our corn. And for the most part, the squash and pumpkins did not provide a living mulch for the soil. The lack of soil cover made it necessary for us to continue to weed the plot throughout the season. The acorn and butternut squash grew scrawny vines that covered very little surface area between the rows of corn. The Cinderella pumpkin had potential to fill out the space with its large leaves and long vines, but its growth was checked by the squash vine borer and cucumber beetle. The Seminole pumpkin, on the other hand, provided a thick canopy of large leaves and vigorous vines that shaded out the soil beneath. Its apparent resistance to many of the pests that plagued Cinderella allowed it to continue growing throughout the season and provide a living mulch for the soil.

Crop Selection

The selection of flour corn, winter squash, and pumpkins allowed us to wait until the end of the season before harvesting, which was a beneficial strategy. These crops fit well into the Three Sisters design because it can be difficult to get into the field while the crops are growing without causing damage to the vining squash or pumpkins. If there are not insect pests or weeds to deal with, a grower would be able to stay out of the field until harvest time when the winter squash or pumpkins are fully ripe. Including pole beans in the system would add another layer of complexity, however, likely requiring harvest before the squash or pumpkins are mature. The production of dried pole beans in the Three Sisters system needs to be explored in subsequent trials.

Variety Profiles

Texas Gourdseed Corn

This flour corn performed well in the 2011 Heirloom Flour Corn Trial at the Kerr Center, but gave low yields in the Three Sisters Trial. The low yield could have been due to close plant spacing, inadequate fertility, or unfavorable weather. Texas Gourdseed has a white, pointed kernel that protrudes from the cob, making it very easy to shell by hand. It showed a susceptibility to corn smut and a frequent occurrence of ear rot during harvest. Further trials would need to

Seminole pumpkin vines filling in the space between the rows of corn.
be conducted to observe its compatibility with pole beans in a Three Sisters planting.

**Waltham Butternut Squash**  
(*C. moschata*)

This popular winter squash performed poorly in our trial. Its vine growth was checked by summer stress and insect pressure, preventing it from providing a living mulch between the rows of corn. Despite its purported resistance to the squash vine borer, we observed some damage, in addition to damage from squash bugs and cucumber beetles. Black rot was significant on the mature fruit, lowering marketable yields. We believe that butternut squash could have potential in a Three Sisters planting if planted on a closer spacing and protected from summer stress and insect pressure.

**Table Queen Acorn Squash**  
(*C. pepo*)

This winter squash also performed poorly in our Three Sisters Trial and was not well-suited for direct seeding in July. We observed slow germination and a very low seedling survival rate, likely due to hot soil temperatures and insect pressure. Throughout the season there was some damage from squash bugs and vine borers, and significant damage from cucumber beetles. Because of these factors, the acorn squash exhibited poor vine growth. Some rot was observed during harvest. We saw less potential in the acorn squash for Three Sisters production, but the variety would need to be grown in less stressful conditions to make decisive conclusions.

**Cinderella Pumpkin**  
(*C. maxima*)

This heirloom was a favorite from the Kerr Center’s 2011 No-Till Pumpkin Trial, but was a crop failure in the Three Sisters Trial. Cinderella
produces beautiful red-orange 15-20 pound flattened fruits in more favorable conditions, but only yielded two small pumpkins in the trial. Though we observed good germination and vigorous seedling growth from the variety, it was overwhelmed by insect pests by early August. Cinderella suffered severe damage from vine borers and received more pressure from squash bugs and cucumber beetles than any of the other cucurbits. It could potentially serve as a trap crop for cucumber beetles, considering they preferred Cinderella blossoms over all the other varieties. We would not recommend growing this variety where these insect pests are a problem.

Seminole Pumpkin (*C. moschata*)

This heirloom pumpkin was the success story of our Three Sisters Trial. It was relatively pest-free until cucumber beetles began to appear in late September, after Cinderella had already suffered significant damage. The light insect pressure might have been due to Seminole’s late flowering, which occurred about a week after Cinderella flowered. It was also able to put out vigorous vine growth, carpeting the area between corn rows with large dark-green leaves. Despite an early freeze cutting the growing season short, this variety set a good amount of fruit, each averaging 5 inches in diameter. The fruits look like pumpkins, but they are closely related to butternut squash and have sweet, deep-orange flesh. Their skin turns from dark green to light tan once the fruit is mature. Seminole showed itself to be a very resilient variety that is well-suited for Three Sisters production.

An immature Seminole pumpkin in the field.
Seed Sources

Texas Gourdseed, Kentucky Wonder Pole, Waltham Butternut, and Seminole were purchased from:

SOUTHERN EXPOSURE SEED EXCHANGE
P.O. Box 460
Mineral, VA 23117
Email: gardens@southernexposure.com
Phone: 540.894.9480
www.southernexposure.com

Hidatsa Shield Figure, True Red Cranberry, and Turkey Craw were purchased from:

SEED SAVERS EXCHANGE
3094 North Winn Road
Decorah, Iowa 52101
Phone: 563.382.5990
www.seedsavers.org

Table Queen Acorn and Cinderella were purchased from:

HIGH MOWING ORGANIC SEEDS
76 Quarry Rd.
Wolcott, VT 05680
Phone: 802.472.6174
www.highmowingseeds.com

Acknowledgments

We would like to acknowledge student intern Rock Gremillion for his assistance with the harvest of corn and squash from the Three Sisters Trial.

Endnotes


5. Effective microorganisms are a microbial inoculant product that contains a variety of beneficial bacteria and yeasts which promote nutrient cycling and can suppress plant disease. We used EM-1 manufactured by TeraGanix.
About the Authors

Luke Freeman was Horticulture Program Assistant at the Kerr Center from 2011 - 2013, after graduating from the University of Missouri. He earned a Bachelor of Science in Agriculture with an emphasis in sustainable agriculture. At the Kerr Center, Luke worked with George Kuepper to maintain and expand the horticultural programs on the farm. He was responsible for composting operations, developing a potting mix from on-farm materials, maintaining and gathering data from the heirloom vegetable field trials, beginning an heirloom seed-saving program, and assisting with farm tours.

Jacob Delahoussaye was student intern at the Kerr Center in summer 2013. He is a student at the University of Louisiana at Lafayette, with a major in sustainable agriculture. He hopes to find a job in a horticulture-related field, and save money to one day buy land to start his own farm.

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