Southern SARE 2017 Producer Grant

Scaling Up Indigo Production in South Carolina

Overview

Farmer Kathy McCullough of McCullough Farms in Kingstree, South Carolina received a 2017 SARE Producer Grant to demonstrate successful methods for growing indigo plants for use in indigo dye production. Her first growing season for indigo at the farm was 2015, when she and husband William McCullough grew several dozen plants known as Guatemalan indigo (*Indigofera suffruticosa*) in their fruit orchard. This is the same variety grown in the 18th century in the Lowcountry of South Carolina when indigo dye was manufactured on plantations and was a major export from Charleston to Europe. A small amount of indigo dye powder (< 5lbs) was produced from the 2015 crop in conjunction with Caroline Harper and David Harper of Chi Design Indigo, a small textile arts business based in Columbia, South Carolina. Production was scaled up in 2016 and, with seeds saved from the 2015 crop, approximately 400 plants were grown on one-quarter of an acre. Two harvests were made to produce approximately 8 lbs of indigo dye powder.

With the 2017 crop, the SARE Producer Grant allowed Kathy McCullough to work with Caroline and David Harper in testing different methods for successful production of an indigo crop that was efficient to harvest and produced a strong blue dye powder. Working primarily with seeds saved from the 2015 crop (many of the 2016 seeds were not viable), approximately 600 plants were grown on one-half an acre. The soil type for this field is Yemasee Sandy Loam (Ym), which an outer coastal plain soil well-suited to growing this type of indigo. The crop was successful, with two harvests (September and October) yielding abundant leaves and stems that were processed to produce 15.9 lbs of high-quality indigo powder. Chi Design Indigo uses dye from the 2016 and 2017 crops to produce a wide range of natural fiber homeware and personal fashion items which are sold primarily to customers in central and coastal South Carolina. A small amount of the dye is also used for indigo dyeing workshops and sold to natural dyers. (www.chidesignindigo.com)

This report provides a summary of the 2017 indigo crop trials.

Planning - February/March

Aerial view of McCullough Farm with indigo field (left) and planting plan (right)

In February/March of 2017 the producer, Kathy McCullough, and David and Caroline Harper planned the layout, installation, and management of indigo plants in 6 beds on a one-half acre plot at the McCullough Farm. The planning included the schedule and scope of work for the following tasks:

- laying out the beds to include one with direct seeding, one with volunteers/re-sprouts from the previous year, two with plugs planted in weed fabric, and two with plugs planted without weed fabric. In keeping with the organic practices at the McCullough Farm (not certified organic), the team decided that no herbicides or chemical fertilizers would be used.
- contracting with a neighboring farmer (Alan Strong) to plow and disc the field to till-in weeds and grasses and prepare the beds with a hiller row bed maker, remove two small trees, and assist with disking between the indigo rows throughout the growing season
- acquiring supplies including weed fabric, seed starting trays and potting soil, and irrigation materials
- starting seeds, transplanting plugs, and maintaining plants with weeding, mulching, and watering as needed throughout the growing season

One of the more significant changes with the project was to change the original plan of testing sheep grazing with portable electric fencing as a method for weed control and natural fertilizer between the indigo plants. The herd of tunis sheep was sold during the winter of 2017 and the team was not able to locate another herd in the area. As a result, we concentrated more on disking weeds with a tractor, and applying some of the aged sheep manure as a natural fertilizer.

Site Assessment - February/March

The indigo field is rectangular in shape and approximately one half-acre in size, with a length of 200 feet and a width of 110 feet. It is oriented in a northwest/southeast direction and receives full sun during the growing season. The field has trees bordering its north and east sides, and pasture to the south and west. It is not subject to extensive wind or runoff.

USDA Web Soil Survey showing indigo field boundary with Yemassee soils

The Yemassee Sandy Loam (Ym) is a soil of the marine terraces of the outer Coastal Plain which is ideally suited for growing *Indigofera suffruticosa*. Listed by USDA as "prime agricultural soil if drained", the soils in the indigo field did not have any immediate ditching or tiling yet are fairly well drained and did not retain water for long periods, only after heavy rain events. The mounding of the beds alleviates concerns about prolonged wetness affecting the indigo plant roots. They are a somewhat poorly drained sandy clay loam with very little slope, with a depth to water table of at least 12 inches, and not rated as hydric.

While *Indigofera suffruticosa* is native to tropical and subtropical regions of South America, it was productive in the Atlantic Coastal Plain soils and climate of South Carolina in the 1700's, and is proving so again in the 21st century. The climate of this area with an average of 50 inches of rain annually and a frost-free period of 230 to 250 days, and the intense summer heat and humidity of July and August resulted in indigo plants with strong growth and extensive biomass production. The leaves, not the stems or flowers, are the primary source of the indican chemical that is converted to indigo dye.

Propagation – April/May

Indigofera suffruticosa seeds in November ready for harvest (left) and seedlings in May (right)

In late April 2017 a total of ten (10) trays were planted to produce 720 plugs (72 plugs per tray) using 2015 seeds (5 trays/360 plugs) and 2016 seeds (5 trays/360 plugs). Seeds were saved from both the 2015 and the 2016 crops, and seeds from both seasons were planted in an organic potting soil mix. Each tray had a clear plastic cover to protect seedlings from frost, retain moisture, and increase soil temperature. A total of 325 plugs (each with multiple seeds) germinated in five (5) trays, and nearly all of these were from 2015 seeds. Seeds planted in five (5) trays did not germinate due to viability problems with the 2016 seeds.

Approximately 95% of the 2016 seeds planted did not germinate. This may be an indication that they were collected too early (still green) or too late (killed by frost), or improperly stored (too moist). After reviewing the steps taken to collect and store the 2016 seeds, the team concluded that it may have been a combination of a late/post-frost collection (since the plants are subtropical) and storage in semi-most conditions in a plastic bin which may have caused mold or incomplete drying.

The seeds and seedlings were maintained with clear covers on cold days and at night to help warm the potting soil and prevent frost damage. Watering was done with a mister ever 2 – 3 days based on how moist the potting soil was. On warm days in April the covers were removed, and by mid-May the covers were no longer needed. The seeds are very small and difficult to separate, so each plug had multiple seeds and seedlings. These were not thinned, but were allowed to grow in clumps. This did not appear to affect the growth of the plants even after transplanting.

The team also determined that, in future growing seasons, the seeds should be started in early April to allow for transplanting in the field earlier in May. Total time needed from germination to transplanting in the field is approximately 4 weeks.

Site Preparation - May

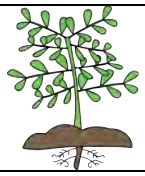
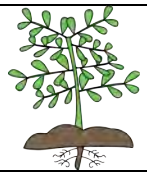
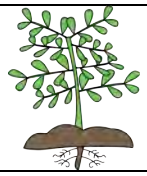
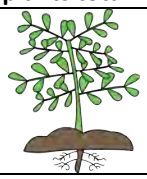
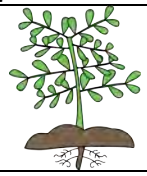
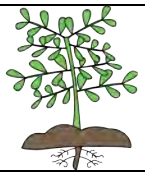
Tractor with disc after preparing and bedding indigo field (plastic weed fabric installed)

In May the half-acre site was plowed with a 4-foot subsoil plow followed by a 4-foot disc plow. The quarter-acre eastern half of the field had been tilled and planted with indigo in the past two growing seasons. This is where Rows 1 and 2 were established – Row 1 was direct seeded and Row 2 was the volunteer/re-sprouts from previous years' crops with no soil preparation. The plowing/disking combination was repeated twice to reduce the amount of nutsedge (*Cyperus rotundus*) present. Two small trees were also removed from an area of the field that had not been tilled in recent years. Prior to planting, a 24" hiller row bedder was used to create mounded rows of tilled soil. The 4-foot disc was used to create weeded strips between rows. Prior to planting, several pickup truck loads of loblolly pine straw had been added to the field, and these were tilled-in in patches. While the initial thought was that this is a good source of organic matter, one concern is that the acidity in the pine straw could inhibit the growth of the indigo plants. These areas of the field were monitored through the growing season for signs of inhibition, which did appear to stunt some plants.

Planting- May


Planting seedlings into bedded rows with felted fiber weed fabric (left) and without (right)

In late May, the weed fabric was laid out (6 mm plastic 48" x 50' for Row 4 and ¼" x 50' felted fiber matting for Row 5) and plugs were planted in 6"x6" holes at 24" intervals. The remainder of Rows 4 and 5, and all of Rows 3 and 6 were planted with seedlings directly into the bedded soil at 24" intervals. The total plants per row were:

Row 1 Direct Seed 38 plants	Row 2 Re-Sprouts 100 plants	Row 3 Plugs, no fabric 98 plants	Row 4 Plugs with Plastic Fabric (47) plugs without (21) 68 plants total	Row 5 Plugs with Felt Fiber Fabric (56) plugs without (26) 82 plants total	Row 6 Plugs, no fabric 77 plants
					
TOTAL 463 plants					

Indigofera suffruticosa 6" seedling in June after transplanting and before most rapid growth

Weeding and Watering – June to September

The team decided that the transplants would only need infrequent irrigation for a short period of 2 to 3 weeks to get them established, provided there was no extended dry period. Williamsburg County is influenced by coastal weather patterns and generally has frequent summer thundershowers, which was the case in 2017. The transplants were hand-watered weekly in the first 3 weeks of June using a garden hose, buckets and a watering can. The team determined that no drip irrigation was needed, however, one could be installed if rains were infrequent.

Indigo rows in July with weed fabric and nutsedge in between (left), sicklepod (right)

By far the most aggressive weed to be dealt with in this field was nutgrass or nutsedge (*Cyperus rotundus*), which is an invasive sedge that reproduces by rhizomes, seed, and underground tubers or "nuts".

Another aggressive weed competing with the indigo by late June and through September was Sicklepod (*Senna obtusifolia*) – a native wildflower that is a legume with a yellow flower and rounded leaflets that look remarkably similar to the cultivated indigo *Indigofera suffruticosa*. They could reach 2 to 3 feet in height and appear like a small shrub shading the indigo and competing for nutrients and water. These were primarily removed by hand pulling and hoeing.

Weeding for both of these species and other weeds was addressed organically with mechanical methods. This consisted of disking between rows every two weeks for a total of 6 diskings, and one extensive hoeing between plants each month for a total of 3 hoeings. Areas with weed fabric required only minor hand pulling of weeds adjacent to indigo plants.

Indigofera suffruticosa in flower in August

Harvest #1 – September


September harvest and harvest crew

The initial harvest in September was conducted by a team of 6 individuals who cut the leafy stems with hand pruners, weighed and tied them with twine into 5 lb bundles, and submerged the plants in stock tanks/cattle troughs filled with 80-degree water, ranging from 140 gallons to 180 gallons in size, to begin the dye production process. Cuttings from each plant are not measured in specific amounts, but the majority of stems are left on each plant for the second harvest and for seed production. A total of 30 bundles with 150 lbs of biomass were submerged in approximately 750 gallons of water. When the dye-making and drying process was completed in November, the yield of dry powder was 4.5 lbs, which is 33 lbs of plant material to produce 1 lb of dye powder.

It should be noted that not all plants are harvested due to the limitations of labor and on-farm dye-processing equipment. Dye processing includes:
- overnight fermentation of the plants in water
- removing the plants from the dye water
- adding pickling lime and aerating with paddles to force the suspended dye particles to settle to the bottom
- skimming off clear top water
- reducing the settled dye to a slurry or mud
- transfer mud to buckets to be poured through cloth filter bags
- hang bags to dry with cakes of dye powder inside
- grind cakes into powder as needed

The results for each row are summarized below:

<u>Row 1 – direct seed</u>
Plants too small to harvest

Row 2 – Re-Sprouts
Plants between 4 and 7 feet in height
50 lbs plant material from 42 plants
Trough 1 – 150 gallons
Yield: 1.5 lbs dye powder

Rows 4 and 5 – Plugs, Weed Fabric
Plants between 3 and 5 feet in height
50 lbs plant material from 47 plants
Trough 2 – 150 gallons
Yield: 2 lbs dye powder

Rows 3 and 6 – Plugs, no Weed Fabric
Plants between 3 and 5 feet in height
50 lbs of plant material from 133 plants
Trough 3
Yield: 1 lb dye powder

TOTAL of 4.5lbs of dye powder from 150lbs of plant matter

Conclusion: Harvest # 1
Starting seeds directly in the ground does not give them enough time to mature and requires more initial weeding than plugs. The re-sprouts produced the greatest amount of biomass and required little weeding and no watering, but did not yield as much dye due in part to their age of 2 to 3 years (as *Indigofera suffruti*cosa plants age, more energy is put into the production of woody stems and branches rather than dye-rich leaves). Plants with weed fabric (either plastic or felt) produce more dye powder and require very little labor in terms of weeding. Planting plugs into weed fabric is the recommended approach.

Harvest #2 – October Field Day


Indigo fields the day of Harvest #2 (left) and harvester bundling/weighing plants (right)


Harvesters submerging plants in cattle troughs (left) with indicant leaching from plants (right)

Aeration of dye water with kayak paddle

The second harvest in October was advertised to farmers, gardeners, and natural dyers as a field day to learn about indigo propagation and cultivation methods and to participate in its harvest. Individuals from the coastal communities of Charleston and Georgetown Counties and the state capital of Columbia participated. The event was promoted with direct mailing and hand delivery of save-the-date cards along with emailed digital versions, followed by an email invitation, along with posts on Facebook. Printed posters announcing the event were posted at locations to attract farmers and gardeners, including Clemson University's Coastal Research and Education Center in Charleston, Grow Food Carolina (food distributor) in North Charleston, Brookgreen Gardens and the Rice Museum in Georgetown, and several other locations.

A team of 20 individuals toured each of the 6 rows to compare production methods and outcomes. They then harvested the plants following the same procedure outlined in the description of Harvest #1. A total of 73 bundles with 365 lbs of biomass were submerged in approximately 750 gallons of water. When the dye-making and drying process was completed in December, the yield of dry powder was 11.4 lbs, which is 33 lbs of plant material to produce 1 lb of dye powder.

<u>Row 1 – direct seed</u>
Plants too small to harvest

<u>Row 2 – Re-Sprouts</u>
<u>Trough 1 – 150 gallons</u>
Plants between 4 and 7 feet in height
60 lbs plant material from 42 plants
Yield: 3.25 lbs dye powder
7 cups lime, 20 minute aeration

Row 2 – Re-Sprouts
Trough 2 – 150 gallons
Plants between 4 and 7 feet in height
65 lbs plant material from 42 plants
Yield: 1.75 lbs dye powder
6 cups lime, 20 minute aeration

Rows 3 and 6 – Plugs, no Weed Fabric
Trough 3 – 180 gallons
Plants between 3 and 5 feet in height
90 lbs plant material from 47 plants
(stomped plants to macerate before submerging)
Yield: 1 lb dye powder
5 cups lime, 20 minute aeration

Rows 4 and 5 – Plugs, with Weed Fabric
Trough 4 – 180 gallons
Plants between 3 and 5 feet in height
100 lbs of plant material from 133 plants
Yield: 1.4 lbs dye powder
4 cups lime, 20 minute aeration

Rows 4 and 5 – Plugs, with Weed Fabric
Trough 5 – 140 gallons
Plants between 3 and 5 feet in height
50 lbs of plant material from 133 plants
Yield: 4 lbs dye powder
2 cups lime, 20 minute aeration

Conclusion: Harvest # 2
Starting seeds directly in the ground does not give them enough time to mature and requires more initial weeding than plugs. The re-sprouts produced the greatest amount of biomass and required little weeding and no watering, and potentially yield more dye when harvested in October, though their age of 2 to 3 years may reduce production of dye-rich leaves. Plants with weed fabric (either plastic or felt) produce more dye powder and require very little labor in terms of weeding. It appears that higher dye yields are achieved when troughs are not packed too densely with plants, which may result in less settling of indican and more of being drained off in top water. Planting plugs into weed fabric is the recommended approach.

Overall Conclusion of Harvests #1 and #2:
In the coastal plain of South Carolina, the best approach to growing healthy *Indigofera suffruticosa* plants which ultimately yield high levels of indigo dye powder is to grow plants from seed into plugs that are transplanted into raised beds with weed fabric at 24" intervals (or even 16"). Spacing between rows may be as wide as 4' for weed control, but could be reduced

to 24” to encourage higher density plantings and shade out more weeds. When processing plants to produce indigo dye, the ratio of plants to water should be in the range of 50 lbs of plant material for 150 gallons of water (1:3)


Indigo harvesters gathered for potluck lunch at Harvest #2


Indigo dye from Harvest #1 (left) used for fabric dyeing at Harvest #2 (right)

Indigo dye cake (left) and powder (right) from 2017 crop

We wish to express our sincere gratitude to all of those who supported our efforts, including professionals with the Southern SARE Program, farmer Alan Strong, and our friends and acquaintances who joined us as harvesters for Harvests #1 and 2

- Kathy McCullough
- Caroline Harper
- David Harper

Looking forward to applying all that we've learned this year in the 2018 growing season!