

UNIVERSITY OF HAWAI'I SYSTEM REPORT



REPORT TO THE 2016 LEGISLATURE

REPORT BY THE DEAN OF
THE COLLEGE OF TROPICAL AGRICULTURE AND HUMAN RESOURCES
ON A TWO-YEAR INDUSTRIAL HEMP REMEDIATION
AND BIOFUEL CROP RESEARCH

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Act 56, SLH 2014 – Industrial Hemp Research Project

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By

Maria Gallo, Dean

College of Tropical Agriculture and Human Resources

University of Hawai‘i at Mānoa

Title: Industrial Hemp, Phytoremediation, Biofuel, and Other Purposes

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Waimanalo, Oahu, Hemp Field Blessing on April 15, 2015

Executive Summary: Industrial hemp is a group of cultivars of *Cannabis sativa* with tetrahydrocannabinol (THC) less than 0.3%. These levels of THC make the plants non-psychoactive. Historically, these cultivars were used for various purposes. For example, hemp was used to make paper. The Declaration of Independence was drafted on hemp paper. It was

also used to make fabrics. The first U.S. flag was made of hemp and for centuries, hemp has been used as a basis for clothing, sails, and ropes. A few decades ago, growing industrial hemp was made illegal and approximately \$500 million in hemp products are currently imported into the United States annually. Section 7606 of the Federal Farm Bill 2014 allows institutions of higher education and state departments of agriculture to grow or cultivate industrial hemp for research purposes. Hawaii's Act 56 allowed the University of Hawai'i at Mānoa, College of Tropical Agriculture and Human Resources to grow and cultivate industrial hemp for research purposes.

The Industrial Hemp Research Project is a feasibility study on the growth and use of industrial hemp in Hawai'i. These studies involved significant paperwork challenges, and it took 11 months to obtain Drug Enforcement Administration (DEA) permits to obtain seeds. Some delay also was experienced because project researchers had to determine what the best method was for seed sprouting.

The sub-objectives of the project included repeating experiments conducted a decade ago in which temperate zone hemp grew to a height of about 2 feet, flowered, and died given Hawai'i's photoperiod. This poor growth proved not suitable for founding an agricultural industry. However, in the current 2015 trials, subtropical fiber hemp grew very well. Evidence has been gathered suggesting that 3 crops a year could be grown in our State. Evidence indicated that this would yield between 27 - 38 tons dry weight of stalks per year depending on densities planted. Similarly, between 31 and 35 tons dry weight of stems and leaves could be obtained per year which could be used as animal forage. A subtropical seed hemp cultivar also grew well. Evidence suggested that 2 crops a year could be harvested and yields of about 2.5 tons of seed could be obtained per acre per year.

Organic material produced in growth experiments was used to project possible future practical applications. Stalks from fiber hemp plants were used to form a building material called hempcrete. When lime (calcium oxide) is combined with hurd (the stalk of hemp plants) the mix solidifies upon standing, producing walls for buildings. Current experiments used commercially available lime and demonstrated that hempcrete could be produced in Hawai'i.

Other local uses, including a homegrown forage for cattle, were also explored. Our research found that subtropical hemp yielded huge amounts of leaves that could be used as forage for cattle.

Finally, food use of hemp seeds was investigated. In Canada, the most lucrative aspect of industrial hemp production has proven to be seed production. Hemp seeds are sold as foods and combined with a number of different products. Because of the many possibilities industrial hemp offers to our local agricultural businesses, the future is promising for this crop in our islands.

Objectives: Objectives outlined in the original proposal have been modified slightly to reflect new opportunities.

1. Find subtropical fiber hemp cultivars and assess their growth characteristics.
 - a. Determine how to sprout the seeds.

- b. Measure growth in comparison to temperate zone hemp plants in terms of overall height, overall weight, stalk weight, leaf weight, and stem weight. Assess growth during different seasons and assess the need for fertilizers, pesticides, and water.
2. Find subtropical seed hemp plants and assess their growth characteristics.
 - a. Determine how to sprout the seeds, and measure growth and seed yield.
3. Use plant materials obtained in growth trials to investigate further uses such as hempcrete from fiber hemp stalks, animal feed from leaves and stems of fiber hemp, and food from seeds.
4. Assess the phytoremediation capacity of industrial hemp.
5. Assess the biofuel potential of industrial hemp.

Anticipated Benefits:

1. A trial was run and repeated. It was estimated that yields in excess of 27 tons dry weight of hemp stalks could be obtained for 3 crops per year. Hurd obtained from stalks could be used to produce a building material called hempcrete. The photo below is a retted hemp stalk. The “stick” portion is hemp hurd. The “skin” portion contains hemp bast fibers which, among other things, may be woven into clothing.



2. Public housing is built of hempcrete in England. While more research needs to be done on this, there can be significant value of a home-grown building material for housing. It also has been reported that hempcrete is termite resistant, recyclable, and breathable. In a later section, experiments are described demonstrating that hempcrete can be made in Hawai‘i with minimal outside assistance.
3. Other attributes of fiber hemp growth were observed. One would not want to import a crop that requires large amounts of water in an island environment with finite fresh water supplies. Industrial hemp required only 10 mm of water per week. One would not want to increase the use of herbicides. Industrial hemp is self-weeding. One would not want to import a crop that would require large amounts of fertilizer. Industrial hemp did not benefit from added fertilizer, although in the future it could deplete the soil and modest fertilizer inputs might be required.

4. Seed importation was a challenge. The main reason is that industrial hemp is classified by the DEA as a Schedule 1 narcotic. It is unclear why industrial hemp is classified as a drug. It took 11 months between starting the process to import hemp seeds for growth trials until the seeds arrived. Importation required assistance from the State to the Federal level, however now a precedent has been established for future permitting.

5. Seed sprouting also proved a challenge, however researchers developed successful techniques resulting in field planted hemp. Hemp seed needs moist, loose soil. This seems trivial, but several months of project time were lost before that was established. Lack of seed germination previously had been misidentified as birds eating seeds planted in the field before they could sprout. Control experiments proved that this was not the case.

6. The fiber hemp also produced large amounts of potential forage for cattle. For generations it has been too expensive to import forage such as alfalfa or hay to Hawai'i. Even high energy feeds such as corn are problematic. They have a high nutritive value compared to their shipping cost. The present work opens a door for forage hemp because it grows quickly, in excess of 30 tons dry weigh/acre/year. It could further expand the cattle industry in Hawai'i. The meat produced would be more nutritious than corn fed beef and would be similar to grass fed beef.

7. Hemp seeds are another promising product. While the size of yields are approximated since we had to harvest seed hemp before they matured, we estimate 2.5 tons of seeds/acre/year. We can harvest 2 crops a year. At one point Canada grew 40,000 acres of hemp per year. All but 10,000 acres went into other crops but the remaining hemp acreage was for seed hemp. They market packets of hemp seeds which people sprinkle on their cereal during breakfast, their salads, or make into cookies. The value of seed hemp is potentially very high. The 2.5 tons/year translates to 88,000 ounces/year. If there are 2 ounces of hemp seeds per candy bar this means each acre of hemp could support 44,000 candy bars a year.

8. The delay in getting seeds and the time needed to learn to grow hemp reduced the time for phytoremediation studies. It is doubtful that hemp seeds would yield biodiesel in a cost competitive way and lignocellulosic ethanol technology is in its infancy. In the fine oils industry somewhere between \$5-15/lb are required to be competitive. There are no commercial plants in the U.S. other than research plants.

Work Progress and Principal Accomplishments:

1. Almost half the grant period (11 months) was required to process the paperwork needed to import hemp seeds. The chief impediment was the DEA.

2. As indicated previously, temperate zone hemp was grown as a negative control. As reported previously by David West, temperate zone hemp grew to a very small size, flowered, and then died in the grow out period. In the present work, grow out trials of temperate zone hemp yielded plants with a mean height of 52 cm and a mean weight of 13 g. In the following photo, these plants are shown behind the flag near the left foot of the student and it is obvious that these cannot be the foundation for an agricultural industry.



The reason for this is that hemp has a critical photoperiod. Temperate zone cultivars will flower and die once day lengths decrease below 14 hours, which occurs often in Hawai‘i.

3. Some time was spent on sprouting hemp plants. The entire field was planted in four separate trials and few plants were obtained. In previous work, this was blamed on birds finding and eating planted seeds. At the suggestion of colleagues, seed trays were used. These are automatically watered with fine mist twice a day. Plantlets are shown in cells and the PVC pipes carrying water sprays are shown in the background.



This would be treating a field crop such as hemp as a horticultural crop which is not desirable. Heavy watering of field planted hemp seeds did not work because it compacted the soil. Waimanalo is relatively dry in the summer. The successful approach was to wait until a couple of rainy days were forecast. At this point hemp seeds were planted. They sprouted and are shown below in the left panel. Juvenile plants that resulted are shown in the right panel at 6 weeks of age. This should be the method that works in the future. Seeds should be planted in rainy weather when hand watering is not desired.



4. May Nakahata of Hawaii Cane & Sugar suggested contacting Ecofibre Industries, an Australian company, to obtain subtropical hemp seeds. One such seed, CHG, is reported to have come from Southeast Asia and bred for good yields in subtropical day lengths. Such day lengths exist in Hawai'i. On the left below is a photo of subtropical fiber hemp at 8 weeks of age out of a total grow out time of 15 weeks. At right is the same type of plant at 10 ½ weeks of 15 weeks. It is noted that the hemp plants are very large and the photos demonstrate how fast the subtropical fiber hemp grows.



5. A pair of trials were done. One trial was between April 29-July 27. The trial was in a (desirable) period of increasing day length from 12h30 min to 13h26 min. Densities were between 20-40 plants/m². A post-season trial was done between July 7-October 7. Day length decreased from 13h15 min to 12h0min which could have been the wrong signal. Densities were 100/m². Measurements were made on every fifth plant harvested. Plant height for both trials was not significantly different. Mean stalk weight was higher at lower density than at higher density. Total stalk weight was higher at higher density than at lower density. Leaf weight was higher at lower density than at higher density but the total weight of leaves was higher at higher

density planting. Total weights were normalized to 3 crops per year as it is likely that a February-April grow out period would be successful. The density farmers would choose depends on their intended commercial application. Do they want larger stalks or a higher yield of stalks? Do they want larger leaves or more total leaves?

	In season (20-40 plants/m ²)	Post season (100 plants/m ²)
Stalk weight	137 g/stalk	78 g/stalk
Total stalk weight	27 tons/acre/year	38 tons/acre/year
Leaf weight	157 g/plant	71 g/plant
Total leaf weight	31 tons/acre/year	35 tons/acre/year

6. Environment: Hemp plants were grown without herbicides. They were self weeding because they grow so densely as to shade out weeds. The photo below shows no weeds even though the plots were not weeded.



We relied on natural fertilizer levels in our trials. Replicates with 100 kg N/ha were not significantly better even though soil chemistry suggested that nitrogen fertilization was recommended. It may be concluded that hemp initially does not require fertilizer inputs. No insecticides were used in our trials. Little water was used. Daily rainfall was monitored. When rainfall was below 10-15 mm/week, manual watering using a calibrated hose nozzle was used to obtain the 10-15 mm/week. Increasing water to 25 mm/week did not yield larger plants.

7. Hempcrete: We conducted cursory hempcrete studies to prove that hempcrete could be made in Hawai'i without special chemicals or knowledge. We purchased a proprietary preparation of lime we found in the peer reviewed literature and used a formula for production found on the internet. We peeled hemp stalks (shown below on the left) to remove the bast fiber "skin". We

cut the remaining hurd into small pieces. We mixed the lime and water first and then added the hurd. When poured into trays (photo on left) we obtained a solid mass. This could be removed from the tray to yield the brick (also shown in the picture on the left). When poured into a cup and the cup material removed, one gets a rock shown on the right.



The formula we used is as follows.

Lime	Water	hurd
1.1 part	1.1 part	0.74

8. Seed Hemp: Two trials were conducted, an in-season trial (defined in #5 above) and a post-season trial (defined in #5). Densities were between 20-40 plants/m². These were called CHY cultivars by Ecofibre Industries, whereas the fiber hemp variety was called CHG. Plants were smaller than fiber hemp plants, seed hemp plants having a mean height of 103 cm and a mean weight of 129 g after the 15 week grow out period. We were not completely clear on estimating seed yields because we were asked to terminate the trial before seeds were completely mature. Half the plants had no seeds. Of the remaining half, some had very few seeds. We could not tell whether these were hermaphrodites or immature plants. Of the plants with heavy loads of seed, mean seed numbers were about 2,000 seeds/plant or 62 g/plant. Seeds were obtained from plants in the in-season trial only. Post-season plants grew to about 6 inches, flowered, and died.

Summary: This was a feasibility study. It was not funded nor was it conceived of as a full-fledged grow out trial. The goal was to learn whether there was a hemp cultivar that would grow in Hawai'i. More complete grow out field trials would have to be done by the industry. Other application work would also have to be carried out by the industry. Two notions were present before the work started. One was that hemp plants would not grow well in Hawai'i. It would grow to a few feet tall, flower, and die. We found that this was true for the temperate zone hemp, however not for the subtropical fiber hemp type.

We found that subtropical fiber hemp grows to a mean of 1.9 m in 15 weeks. We were pleasantly surprised by the fast growth rate. More interesting, this variety of plant can take advantage of Hawai'i weather patterns and potentially 3 crops per year could be grown. The yield of about 30 tons per year of stalks per acre is promising because there is need for a building material in Hawai'i that is not imported. The large amount of leafy material from fiber hemp offers the potential for a home-grown forage crop to feed local cattle. Hemp seed production may become a lucrative activity for farmers. There is significant potential for a successful hemp agricultural industry in Hawai'i based on the preliminary findings of the 2015 Industrial Hemp Research Project.