Industrial Hemp Field Guide

PLANTING AND HARVESTING

Legacy Hemp, LLC

TABLE OF CONTENTS

PLANTING & CULTIVATION GUIDE

HARVEST & STORAGE GUIDE

Industrial Hemp Planting & Cultivation Field Guide

1) <u>Regulations and Paperwork</u>

- Each State's Industrial Hemp Pilot Program is different so knowing your own State requirements are important.
- Generally, each farmer will be required to:
    - Obtain a Grower License
    - Apply annually to grow
    - Test hemp plants for THC
    - Receive certification/confirmation that the plants are allowed to be sold

2) <u>Morphology</u>

Male hemp plant

- Hemp is a dicotyledonous plant (having two cotyledon leaves) and has both *monecious* (male/female flowers on the same plant) and *dioecious* (separate male plants and female plants) plants)
    - Hemp is naturally a dioecious variety and most agronomic varieties are as well
        - The ratio of male to female plants is typically 1:1

- Hemp is a cross-pollinated, wind-pollinated plant. Only male plants produce pollen (dioecious plants). The flowers on the inflorescence open from the bottom of the plant first then to the top of the plant. Once the male plants have fully shed their pollen they will senesce and die. Pollination typically lasts 2-3 weeks depending on weather conditions and uniformity of the stand. It is said hemp can produce more pollen than all other cultivated crops. The pollen from hemp can travel up to 10 miles.

Female hemp plant

Female hemp plant with arrows depicting the styles.

- While both male and female flowers can be identified at the nodes of the plant, female flowers can be differentiated by the enlargement of a symmetrically tubular perigonal bract and the protruding white style. The initial male flowers have a curved claw shape that will then develop into round pointed pollen sacs that have five radial segments. Males will not have the white style like those found on female flowers.
  - Male plants are the first to show signs of flowering with the staminate visible at the nodes of the plant. Flowering typically begins 4-6 weeks after planting. Female plants can usually be identified 5-14 days after the males.
- Hemp is photoperiod-dependent and is considered a “short-day” plant.
  - The vegetative phase turns to reproductive phases only when the daily exposure to sunlight is shorter than a specific maximum duration (**critical day length**)
    - 14 hours or less of daylight will typically trigger flowering.
      - Shorter day length can accelerate the onset of flowering

Hemp roots

- The root system of hemp typically reaches depths of 1-2 feet in the soil.
  - Wet soils will keep root systems shallow while drier soils encourage deeper rooting.
    - Sandy and loamy soils generally allow for larger root formation
  - Female plants have much larger and stronger root masses than male plants.
- Stalk height and thickness is significantly affected by soil type, fertility and physical/chemical characteristics of the soil
  - Stalk length is influenced more by nitrogen while stalk thickness is influenced more by plant density and row spacing.
  - Light (sandy) to medium (loamy) textured soils tend to grow much taller plants than heavy (clay) soils due to better drainage and less compaction.
  - Seed/grain varieties typically stand 4-6 feet tall at harvest. Fiber varieties can reach heights of 8-14 feet by harvest.
- Hemp grown for seed grows much slower, initially, than hemp grown for fiber. However, near the end of the vegetation stage, seed hemp grows much more rapidly.
  - Weed suppression is less effective with grain varieties than with fiber varieties.
- Hemp can grow 1-2 inches per day during its rapid growth stage which typically begins 4-6 weeks after planting.

3) Climate and Soil Requirements

3.1) Inclement Weather

Excess Moisture

- Excess moisture during the growing season, especially during the early stages of growth (Day 1-30), has the potential to cause the most severe yield loss than any other individual factor when growing hemp. The growing point is typically the first part of the plant that is affected by heavy rains. However, once hemp has reached a height of approximately 12 inches (4-5 weeks after planting) problems due to excess moisture are reduced.
- Excess moisture can induce a list of problems:
  - Seed and seedling pathogens that can ultimately kill the plant
  - Germination can be delayed until soils dry out
  - Reduced plant stands and uneven stands
  - Reduced seedling vigor and competitiveness
  - Reduced root size which can stunt plants and subject them to drought problems
  - Nutrient deficiency, especially nitrogen
  - Soil erosion can Increase/decrease seeding depth
  - Crusting and Compaction
  - Increased weed pressure
    - Each rain event allows for more weed seeds to germinate
    - Weed pressure in organic systems will be the most critical pest.
- Heavy rains between planting and before emergence can have the largest impact on final yield.
  - If hemp experiences more than 1 inch of rain between planting and emergence, great consideration should be given on resulting plant stand counts to determine if replanting is necessary.
  - Plants can tolerate flooded areas for only 1-2 days before significant damage has occurred.
  - Planting **after** a rain may be more beneficial for seedling development.
    - Consideration should be given to watch the 3-5-day forecast to find a window that does not include rain. Planting should begin at the beginning of this phase to allow for good germination in *moist soils* while also reducing weed seed germination during the same dry period.
- **Soil moisture should be monitored to determine when to sow hemp. Light or sandy soils will need moist conditions to germinate hemp seed. Heavy or clay soils should be planted during drier periods to reduce excess moisture problems.**

Excess moisture in hemp field

Hail

- Hail damage can have a significant impact on yield and quality of hemp.
    - Grain varieties tend to be more resistant to hail damage due to their shorter stature and less of a desire for high quality fiber.
        - Shorter varieties are also less prone to lodging during high wind events.
    - If hail damage occurs early in the growing season, damage is less significant
    - If the apical meristems (growing point) is damaged by hail, hemp may respond by developing new shoots and branches that will continue to grow.

3.2) <u>Photoperiod</u>

- Hemp is photoperiod-dependent and is considered a “short-day” plant.
    - The vegetative phase turns to reproductive phases only when the daily exposure to sunlight is shorter than a specific maximum duration (**critical day length**)
        - 14 hours or less of daylight will typically trigger flowering.
            - Hemp usually begins to flower 1-2 weeks after the Summer Solstice (June 21st).
            - Shorter day length can accelerate the onset of flowering
- The amount of light required by hemp depends on two factors
    - 1) The total amount of sunlight during the vegetative period
    - 2) Day Length - the daily period of sunlight
- Dry matter yield of a fiber crop is more influenced by the daily period of sunlight than the total amount of sunlight during the vegetative phase.
    - Northern latitudes have longer periods of sunlight during summer months.
- Fiber quality, primarily fiber strength, is more influence by the total amount of sunlight during the vegetative phase than by the daily period of sunlight.
    - Early plantings allow for a longer vegetative phase which expose plants to the highest total amount of sunlight during the vegetative period.

3.3) <u>Moisture</u>

- While hemp is fairly drought tolerant it still needs approximately 20-30 inches of moisture per growing season.
    - This is a similar requirement as what is needed from corn.
    - A minimum of 10-14 inches of precipitation during the vegetative period is required for optimum growth.
        - Rapid growth stage accounts for the largest water consumption period
            - This is the stage that determines yield
- Drought tends to hasten maturity before plants are fully grown and can dwarf plant growth in severe droughts.

3.4) Temperature

- Hemp can germinate in soil temperatures near 34-36 °F. Some research has shown that early planted hemp can tolerate early frosts of temperatures down to 23°F. After the 3rd pair of leaves, hemp can survive temperatures of 30 °F for 4-5 days.

Frost damage on hemp seedlings

  - Faster sprouting begins at soil temperatures of 45-50 °F (8-12 days).
  - Rapid germination (1-3 days) and emergence occur at soil temperatures above 55 °F (3-8 days).
- It is recommended to plant when soils are warm and can promote rapid germination and emergence. This allows for quick establishment and the best opportunity to compete with weeds and other pests.

- The optimal air temperature for growing hemp is between 66-77 °F.
  - Average daily temperatures of 61 °F will allow for the rapid growth stage to commence.

3.5) Soil Requirements

- Hemp tends to grow best on well-drained soils with good fertility. Sandy and loamy soils provide the best opportunity for growing hemp. Heavy Clay soils tend to pose more challenges for hemp due to the increased risk of compaction, reduced drainage and cooler soil temperatures.
  - Fiber hemp should specifically avoid being grown on high organic matter soils (muck soils).
- Avoid marginal soils with low fertility.
  - Hemp grown on poor soils will lack the vigorous growth needed to outcompete weeds
- Fields of choice should be those that provide the lowest weed pressure and the highest yields.
- Crusted soils will result in significant losses in seedling emergence. Efforts should be made to break the crust using irrigation or mechanically, using a rotary hoe or harrow.
  - A replant may be necessary if efforts to break the crust are unsuccessful and plant stands are reduced and weed pressure is high.
- Hemp does not tolerate saline soils

3.6) Rotation Effect

- Some of the rotational benefits of growing hemp include:
  - Improved soil structure
  - Improved soil tilth – soils tend to be more mellow and easy to work in the spring
  - Improved infiltration and soil moisture
  - Soils tend to warm more quickly in the spring
  - Improved nutrient cycling

- Reduced nutrient leaching
- Good weed control
- Potential yield increases in subsequent crops

4) Fertility

4.1) General

- Ideal pH range is 6.5-7.5
- Hemp is most responsive to nitrogen and phosphorus fertilizers but it is important to balance nutrient applications. Excess nitrogen combined with inadequate potassium can result in lodging.
- Nutrient demand increases with plant age and is greatest during the flowering stages, especially phosphorus.
- Sulfur applications should be 15-25 lbs/ac
- If tissue samples are taken to determine nutrient deficiencies, Canola should be used as the base crop.

4.2) Nitrogen

- Hemp is a high nitrogen user and has been known to remove 175 lbs/ac of nitrogen from the soil – 35 lbs/ac in the seed and 140 lbs/acre in the fiber
    - Hemp can uptake approximately 6 lbs/ac per day of Nitrogen during its rapid growth phase.
- Fertilizer applications are recommended at approximately 100-120 lbs/ac of nitrogen.
    - Increasing nitrogen rates beyond 125 lbs/ac may delay seed maturation.
    - Seed placed nitrogen can reduce germination. Care should be given to the type and amount of fertilizer applied at planting.
    - Slow release nutrients or split applications make for the best types of fertilizers to match plant uptake.
    - Foliar applications of nitrogen are less successful than soil-applied nitrogen.
- The majority of nitrogen is stored in the stalk so removal of the fiber can result in higher nitrogen requirements for the subsequent crop.
    - If the hemp fiber is left to field-ret, the stalks will leach a large percentage of nitrogen and potassium back to the soil.

4.3) Phosphorus

- Hemp requires moderate amounts of phosphorus and can uptake approximately 1.3 lbs P/ac/day during its rapid growth phase.
    - The majority of phosphorus is contained in the seed and therefore maintaining phosphorus availability during flowering and seed maturation is important.

- Application rates of phosphorus should be approximately 40-70 lbs/ac
    - Available forms of phosphorus are important during the early stages of seedling growth.
    - Avoid seed-placed phosphorus during inclement weather at planting – cool, wet, dry or compacted situations

4.4) Potassium

- Potassium should be applied at a rate of 60-100 lbs/ac
- Chloride fertilizers, such as Potassium Chloride, should be avoided since chloride ions can be detrimental to fiber development, reducing fiber quality.
- Potassium is leached out of the stalks during the retting period.

5) Planting

5.1) Field Selection

- Hemp production is best following an alfalfa crop or legume cover crop. Good yields can be obtained following soybeans, barley and potatoes.
- Hemp production is limited following corn, canola and sunflowers due to higher nutrient requirements of these crops.
- Fields of choice should be those that provide the lowest weed pressure and the highest yields.
    - In organic systems, the most important factor in selecting fields should be based on the reduction of weed pressure.
- Scenarios that reduce weed pressure in organic cropping systems include:
    - Selecting the highest yielding fields.
    - Planting hemp after a sod legume such as alfalfa or clover.
        - Corn and soybean fields allow for the highest potential for weed pressure in subsequent years.
    - Avoid fields that are prone to drought or standing water.
    - Cover crops, like winter rye, may provide some weed control in the spring before termination but may not provide as much control as planting after a sod crop like alfalfa or clover.
        - Allelopathy may inhibit growth due to the relatively small seed size of hemp. Termination of rye cover crop should occur 10-14 prior to planting to avoid allelopathy concerns.
    - Plant after a rain not before.
        - **Planting in moist soils during a dry period** allows for the hemp seeds to germinate while weed seed germination is limited.
        - Dry, sandy soils may need rain or irrigation to germinate seed.
    - Since hemp's root growth is quick to develop in the first 3 weeks of growth, use of the rotary hoe, tined-weeder or harrow may be possible to assist in early season weed control.

- Research on the viability of these methods is limited so careful application must be observed.
- Timing will be important as to not get out to early and dig up seedlings but not too late to reduce weed control effectiveness.
    - Hemp seedlings with 2-3 inches of root growth (10-14 days after planting) may tolerate these weed control methods.
        - Evaluation should be considered on a small area before attempting the entire field.

5.2) Seedbed Preparation

- A shallow, firm seedbed allows seed to be placed at a uniform depth, resulting in more even seedling emergence. Seedbed preparation should be similar to alfalfa and clover establishment.
    - Rolling and packing the soil is good practice after seeding if soils are not too wet – compaction can stunt plants.
    - Seeds require good seed-to-soil contact for uniform germination.
- The last pass of tillage should occur as close to planting as possible (preferably same day).

No-till industrial hemp

No-till planting can be successful if the field has a history of low weed pressure and is warm and moist enough to encourage rapid germination and emergence (>55°F soil temperatures).

- Burndown herbicide use prior to planting may be necessary in conventional operations.

- Cover crops can be successfully underseeded with industrial hemp. Shade tolerant varieties are recommended – clovers, vetch and possibly alfalfa.
- It is recommended to limit planting hemp more than 2 consecutive years on the same field to avoid increased risk of pest problems, particularly diseases.

5.3) Dates

- Because hemp is highly responsive to daylength, seeding dates are less critical than obtaining optimum seeding conditions (i.e. soil preparation, weather, pest reductions).
    - Seeding dates in Wisconsin range from the end of May to the end of June. More northern geographies should avoid planting beyond mid-June.
- Earlier plantings will allow for larger plants and likely higher yields. However, conditions that allow for rapid germination and emergence should be considered the primary factor in determining actual planting date.

- Planting date should coincide with soil temperatures at or above 55°F. This will allow seedlings to emerge within 3-5 days after planting and provides the best opportunity for the hemp plants to outcompete weeds and avoid cool, wet soil conditions that can stunt plants.
  - Generally, planting hemp after other cash crops (corn, soybeans) have been planted is good practice.

5.4) <u>Depth</u>

Determining seed depth

- Seeding depth TARGET– ½ inches
- Seeding depth RANGE – ¼ - ¾ inches
- Planting equipment can include:
  - Grain Drill
  - Brillion Seeder
  - Broadcast Seeder
  - Air Seeder
  - Air Drill
  - Corn Planter
  - **Roller or Cultipacker**
    - A firm seedbed is important for uniform germination and emergence.
- If a grain drill is used to plant hemp seed, it must be capable of adjusting the seeding depth. Older grain drills typically place the seed too deep.
  - Seed planted deeper than 1-inch may experience prolonged emergence resulting in uneven stands and reduce vigor and competitiveness with weeds.
  - If grain drills do not have a means to control depth, a different method of planting may be recommended.
- If using an air drill, reduce air volumes to avoid cracking seed.
- It is important to precisely measure seeding depth. It is good practice to check and re-check seeding depth from field to field as soil conditions may change.
  - Use of a ruler to determine actual depth is good practice

5.5) <u>Seeding Rate & Stand Assessment</u>

- Planting seed is typically 90-95% germination in the first year after harvest. Germination rates decline to 75-80% the second year after harvest.
- Seeding Rate should be approximately 25-35 lbs/ac (~800,000 seeds/ac – 18 seeds/ft^2) for grain hemp and approximately 50-60 lbs/ac (~1.5M seeds/ac – 35 seeds/ft^2) for fiber hemp
  - Using a grain drill, seeds per linear foot should be approximately 6 seeds per foot
  - Stand counts for grain should be in the 600-750k plants/ac (13-18 plants/ft^2) range to obtain adequate weed control. Counts less than 350k plants/ac (<8 plants/ft^2) should be evaluated for weed control and considered for replant.
  - Organic farms should consider seeding at the higher range to aid in weed control.
- Be sure to calibrate planter before seeding all acres.

  - A starting point for grain drills may be close to oats or barley setting.
  - A starting point for the grass seed box or Brillion seeder may be close to the millet setting.
- A 15-30% reduction in seeding rates should be observed when increasing row width by 4-5 inches, see chart below as a guideline.

The Cultivation of Hemp - Bocsa, Karus

Row Width (in)	Seed Quantity (lb/ac)	Sprouted Plants (per ft^2)	Sprouted Plants (per acre) *
8	22-27	12-14	500-600
12	16-20	8-10	360-450
16	11-13	6-7	240-300
20	9-11	5-6	200-240
24	7-9	4-5	160-200
28	5-7	3-4	120-160

* Multiple of 1,000

- The wider the rows that hemp is planted, the higher the potential for more branching and seed-bearing structures. Plant height and stalk thickness may also increase by widening rows.
  - Seeds on lower branches, if harvested, may increase harvest problems due to increasing the amount of fiber brought through the combine.
  - Wider rows may allow for cultivation during the growing season.
- Fields with a history of high weed pressure should be planted at higher seeding rates to allow hemp to “choke out” weeds.
  - Higher seeding rates may allow for smaller stalks and ultimately less fiber that is run through the combine.

5.6) Seed/Seedling Mortality

- Industrial hemp tends to have a high rate of seedling mortality. Mortality can be caused by many factors – seeding depth, soil moisture (too wet/dry), poor seedbed preparation, seed cracking from the planter, soil temperatures too cool, insect feeding, seedling disease, compaction, etc.
- Seedling mortality can range from 10-70%
  - 30% mortality is used as the industry average.
  - Mortality rates in 2018 in Wisconsin ranged between 20-50%.
- Adjustments to seeding rates may need to be considered if seedling mortality tends to be higher than average for a particular field or area.

6) <u>Growth Stages</u>

The below growth stages were depicted from the book, *The Cultivation of Hemp by Bocsa, Karus*

The growth and development stages of hemp can be divided in to 6 different stages

6.1) <u>Germination</u> – this stage lasts until the development of the first pair of true leaves reaches the size of the cotyledons

- Under normal conditions, a rootlet appears 24-48 hours after seeding. Shortly after this period, the vegetative bud appears with both cotyledons, from which the hypocotyl develops.
  - Upon emergence, the cotyledons are still yellow but will gradually turn green.
- After the cotyledons open, the small bud rapidly develops and produces the epicotyl (seedling stem). Simultaneously, the first pair of true leaves develops.

Seedling emergence

6.2) <u>Stage of Slow Growth</u> – this stage is from the appearance of the first pair of true leaves until the growth of the fifth set of leaves.

- 4-5 weeks after germination
-
- Plants develop slowly and reach a height of 15-20% of their final height (10-12 inches).
- 9-10 days after germinating, the second pair of true leaves develop.
- 15-16 days after germinating, the 3rd pair of true leaves develop.
- After roughly 25 days, the fourth and fifth leaves develop.
- Weed control during this time is absolutely critical – use of a rotary hoe, tined-weeder or harrow may be necessary

Slow growth stage

6.3) <u>Stage of Rapid Growth</u> – this stage begins at the 5th set of leaves until the formation of flower buds.

- 6-12 weeks after germination
- Plants develop quickly and require the highest levels of nutrients, moisture and temperature.
- Plants can grow 3.5 feet in 40 days (Approx. 1 inch per day) – 60% of height
  - Some varieties and environmental conditions will allow 1-3 inches growth per day.

Rapid growth stage

- Fertilization just prior to rapid growth may provide the greatest response in the plant, especially nitrogen applications.
- Foliar applications of micronutrients may be warranted during the rapid growth stage.

6.4) <u>First Reproduction Stage</u> – this is the stage between the growth of flower buds and the time the first flowers open. The first stage is called the GV point, when leaves on the main stem change from opposite to alternate.

- 13-18 weeks after germination
  - Plants develop more slowly again and reach the last 15-20% of their final height (5-6 feet for grain varieties).
  - Growth ceases after flowering ceases.

Male plant beginning to flower

- The number of days to the onset of flowering is primarily dependent on the photoperiodic reaction (critical day length).
  - Generally, 1-2 weeks after the summer solstice (June 21st)
  - Shorter daylength accelerate the onset of flowering
- 4-6 weeks pass from the emergence of flower buds until full flowering

6.5) <u>Flowering</u> – This stage begins when the anthers on the first male flowers open and release their pollen until the flowers in the upper 1/3 of the inflorescence open and their pollen is released.

- Pollination typically lasts 2-3 weeks depending on weather conditions and uniformity of the stand. Once the male plants have fully shed their pollen they will senesce and die.
- Seeds begin to develop 4-6 weeks after pollination begins

Male flowers releasing pollen

6.6) <u>Growth of the Achene</u> – this stage lasts from the swelling of the seed embryo to the maturation of the seed.

- Growth of plant ceases while seeds develop and mature.
- Seed maturity occurs 4-6 weeks after development of the seed.
- Generally, seeds will mature approximately 90-100 days after planting with harvest occurring 100-120 days after planting.

Mature female grain head

7) Pests

7.1) Weeds

- Fields of choice should be those that provide the lowest weed pressure and the highest yields.
    - In organic systems, the most important factor in selecting fields should be based on the reduction of weed pressure.
- Scenarios that reduce weed pressure in organic cropping systems include:
    - Selecting the highest yielding fields.
    - Planting hemp after a sod legume such as alfalfa or clover.
        - Corn and soybean fields allow for the highest potential for weed pressure in subsequent years.
    - Avoid fields that are prone to drought or standing water.
    - Cover crops, like winter rye, may provide some weed control in the spring before termination but may not provide as much control as planting after a sod crop like alfalfa or clover.
        - Allelopathy may inhibit growth due to the relatively small seed size of hemp. Termination of rye cover crop should occur 10-14 prior to planting to avoid allelopathy concerns.
    - Plant after a rain not before.
        - **Planting in moist soils during a dry period** allows for the hemp seeds to germinate while weed seed germination is limited.
        - Dry, sandy soils may need rain or irrigation to germinate seed.
    - Weed control within the first 30 days after planting is the most critical time period.

Seedling growth 14 days after planting

- Since hemp's root growth is quick to develop in the first 3 weeks of growth, use of the rotary hoe, tined-weeder or harrow may be possible to assist in early season weed control.
- Research on the viability of these methods is limited so careful application must be observed.
- Timing will be important as to not get out to early and dig up seedlings but not too late to reduce weed control effectiveness.
- Hemp seedlings with 2-3 inches of root growth (10-14 days after planting) may tolerate these weed control methods.
    - Evaluation should be considered on a small area before attempting the entire field.

Rotary hoeing hemp field

- Planting hemp in rows to allow for cultivation may be another good option for controlling weeds during this critical time period.

- Grass weeds tend to be more problematic during wet conditions. Hemp growth is reduced with excess moisture while grass weeds like foxtail and barnyardgrass tend to grow well in wet conditions. These conditions may allow weeds to outcompete hemp growth and significantly reduce yields.
- Volunteer Wheat, Barley and Buckwheat are difficult to clean from the grain and could lead to rejection at the processor. Care should be given to control volunteer crops prior to growing hemp.

7.2) Diseases

- The two most significant diseases in industrial hemp are *Botrytis cinerea* (Gray Mold) and *Sclerotinia sclerotiorum* (White Mold or Hemp Canker as it's known in Europe).
    - Both diseases can cause economic damage and may result in yield loss and poor-quality seed.
    - Crop rotation considerations should be managed properly to reduce the occurrence of both diseases.
        - Gray Mold Hosts – Over 200 hosts, mostly dicotyledon plants – Sunflowers, Potatoes, Peas, Edible Beans
        - White Mold Hosts – Soybeans, Sunflowers, Canola, Edible Beans, Flax, Potato

Gray Mold (Botrytis cinerea)

- Gray Mold is the most common disease of Cannabis
- Conditions for the development of Gray Mold occur in high humidity and cool to moderate temperatures. The disease peaks in drizzly, maritime climates, including foggy nights.
    - During peak times of infestation, this disease can reach epidemic proportions and destroy an entire crop within one week.
- Gray mold typically infects plants through wounds or any senescent leaves and flowers where it then invades the rest of the plant. Research has shown that male plants tend to be infected first and then spreads to female plants.
- Symptoms of Gray Mold occur in both flowers and stalks.

Gray Mold in hemp

    - Flower infestations begin within the flower buds and initial symptoms are not visible.
        - Once flowers have been infested, the entire inflorescence turns brown, withers and dies
        - In high humidity, whole inflorescences become enveloped in a gray fuzz, then degrade into gray-brown slime. In low humidity, the gray fuzz does not seem to emerge.

- Stalk rot begins as chlorotic discolorations of the outside fibers. These chlorotic areas turn into soft shredded cankers. Stalks can snap or break at these cankers causing lodging.
  - In high humidity, cankers can become covered by conidia.
  - Small, black sclerotia may form within stalks.
- *Botrytis cinerea* can overwinter in infected seeds and within stalk residues as sclerotia hyphae. Infected seeds can also mold in storage and give rise to seed-borne infections of seedlings the following spring.
- Methods to mitigate Gray Mold occurrence:
  - Avoid planting in shaded areas in humid climates
  - Avoiding high density stands (lower seeding rates)
  - Avoid wounding plants (reduce mechanical cultivation)
  - Higher soil calcium levels may help
  - Use of Biocontrol products
    - *Gliocladium roseum or Clonostachys rosea*
    - *Trichoderma harzianum (*Trichodex*)*
    - *Trichoderma polysporum*
    - *Trichoderma virens*
    - *Trichoderma viride*
    - *Streptomyces griseoviridis*
    - *Coniothyrium minitans*
    - Post-Harvest control
      - Yeasts
        - *Pichia guilliermondii*
        - *Candida oleophila*
      - *Pseudomonas syringae*

White Mold (Sclerotinia sclerotiorum)

White Mold in hemp

- Conditions for the development of White Mold occur in cool, moist and humid weather conditions (especially cool, foggy nights). Additionally, dense canopies that reduce air movement can also create microclimates that are prime for white mold occurrence.
  - Sclerotia bodies can overwinter in residue and therefore avoiding growing host crops prior to hemp should be observed.
  - Avoid fields that are prone to white mold outbreaks.

- Symptoms usually begin in late summer on full-grown plants. Water soaked lesions appear first, on stalks and branches. In humid conditions, the surface of the stalk can become enveloped in a white mold. Black sclerotia bodies can form on the exterior of stems or within the hollowed-out stem. Pre-mature death of plants may occur.

White Mold – Left, advanced stage; Right, beginning stage

Female flowers typically die from top to bottom

▪ During wet conditions dead flower heads can act like a sponge and may promote sprouting of seeds prior to harvest.

▪ Healthy flower heads tend to wick moisture away due to the oily surface of the leaves and bracts.

Additional Information

- Higher density stands, like those in fiber crops, can cause more severe problems.
- Sclerotia bodies can sometimes be found in the harvested grain and may be subject to rejection at the processor.
- Occasionally, a secondary fungus, Red Boot Disease, may overgrow on the affected areas of the plant.

Methods to mitigate White Mold occurrence:

- Deep plowing of residues
- Long rotation (3-4 years) between host crops
- Avoiding high density stands (lower seeding rates)
- Avoid using seed from infected plants

Stalk discoloration due to White Mold

- Use of Biocontrol products
    - *Trichoderma harzianum*
    - *Bacillus subtilis*
    - *Coniothyrium minitans*
        - ContansWG
        - *Koni*

7.3) Insects

- While there are many insect pests that can cause problems in hemp, infestations have rarely shown to have an economic impact that would require additional corrective management in outdoor-grown crops.
- some of the most common insects found throughout industrial hemp fields include:
  - Spider Mites (primarily greenhouse problems), Aphids, Whiteflies, European Corn borer, Hemp Borers, Budworms, Cutworms and Armyworms, Japanese beetles and Grasshoppers

Japanese Beetles on male inflorescence

Seedcorm Maggots feeding on hemp seedling

Seedcorn maggot was found in many fields in Wisconsin during the 2018 growing season and were considered to be a factor in stand loss and yield reduction.

- Migratory birds can cause significant yield loss in grain hemp when grown in geographic areas that are within the migration routes.

Additional Resources

- The Cultivation of Hemp: Botany, Varieties, Cultivation and Harvesting – Dr. Ivan Bocsa, Michael Karus
- Hemp Diseases and Pests: Management and Biological Control – J.M. McPartland, R.C. Clarke and D.P. Watson
- Canadian Hemp Trade Alliance (eGuide)
  http://www.hemptrade.ca/eguide
- Growing Industrial Hemp in Ontario
  http://www.omafra.gov.on.ca/english/crops/facts/00-067.htm
- Industrial Hemp Production and Management (Manitoba)
  https://www.gov.mb.ca/agriculture/crops/production/hemp-production.html
- Hemp Production in Saskatchewan
  http://publications.gov.sk.ca/documents/20/84152-Hemp%20Production.pdf

Industrial Hemp Harvest and Storage Field Guide

8) Specifications/Grading

- Cleanliness: 99.9% Pure
- Moisture: 9%
- Seed Size: between No. 5.5 Slotted (5.5/64 x 3/4) and No. 14 Round (14/64)
- <1% green seeds after cleaning
- None – orange or brown 'meats' after hulling
- <2% yellow 'meats' after hulling
- <0.1% sclerotinia
- None – pesticides, fungicides or herbicide chemical residue

Microbial Specification Standards	
Standard Plate Count	<100,000 cfu/g[1]
Total Coliforms	<1000 cfu/g
E. coli	Negative
Salmonella	Negative
Yeast & Mold (combined)	<1000 cfu/g
THC	<10 ppm[2]
Free Fatty Acid	<2%
Peroxide	<2meq/kg[3]
Gluten	<20 ppm

Reminder: Quality is the most important aspect of this crop.

1 - cfu/g - colony forming unit per gram or the measure of viable bacterial or fungal cells.
2 - ppm - parts per million
3 - meq/kg - milliequivalents per kilogram

9) Documentation

- Need to call or email the Department of Agriculture 30 days prior to harvest
    - They will test for THC 2-weeks prior to harvest
    - Fields testing over 0.3% will need to be destroyed
- **Need documentation prior to receiving grain**
    - Fit for Commerce Certificate
    - Organic Certificate

10) Pre-Harvest

10.1) Equipment

- Building shields around belts, pulleys and other moving parts is recommended. This includes final drives on the underside of the combine.
- Prior to harvest, be sure all equipment (combine, augers, trucks, grain cleaners and storage bins) are dry and free of any foreign material or other grains.
    - This will reduce the amount of foreign material taken to the cleaner/storage which results in lower dockage.

10.2) Assessing Maturity

Nearly mature grain head

- Mature seed (60-80%) – 90-100 days after planting
- Harvest time – 100-120 days after planting (September/October)
- Seed maturation begins at the bottom of the seed head and moves upwards. Seeds also ripen from the inside of the seed head and then move outward as maturity progresses.
- Mature seeds (bottom of seed head) will have a tan-brown appearance. Immature seeds (top of the seed head) will be green in color. Mature seeds will be resistant to compression while immature seeds will be easy to squeeze and compress.
- As the seed bracts ripen, they become brownish in color and firm to the touch. The bracts will also shrink in size exposing the seed which increases the chance of shattering.
    - Bird damage can be significant and may cause shattering
    - X-59 has better shatter resistance than other varieties
- Grain moisture at harvest varies depending on variety. Shorter varieties are generally harvested at lower moistures than taller varieties. Taller varieties are harvested at higher moistures due to the desire to maintain more moisture in the stems/fibers to reduce fiber wrapping in the combine.
    - Desired moisture of X-59 at harvest – 12-18% moisture

- Desired moisture of X-59 for storage – 9%

- When grain is harvested at higher moistures, the seed heads will remain mostly green. Some leaves on the grain head will start turning brown. Leaves throughout the stem will have turned brown and fallen off.
- High moisture grain requires aeration within 3-6 hours after harvest to avoid heating and spoilage. Cleaning the grain immediately after harvest can allow 1-2 additional hours before spoilage begins.
  - Seeds that begin to heat will oxidize and produce poor quality oil and food products. The color of the seeds will change when spoilage occurs and is subject to rejection.
  - Combining should be performed at a rate that can guarantee enough time to deliver the grain to a storage facility that can clean and dry the grain within 3-6 hours after harvest.
    - Drive time to facility should be factored
    - DO NOT LEAVE HARVESTED GRAIN SIT OVERNIGHT WITHOUT AERATION.
  - Required dry moisture of grain is 9%
- Hemp can tolerate moderate frosts (23°F) for a short period of time without damage to mature seeds.
  - A killing frost will act as a desiccant and will hasten maturity. Harvest is recommended within 2-4 days after a killing frost to prevent yield loss and to reduce fiber drying which can increase fiber wrapping.

Mature grain head with seed bracts exposing seeds

Seed bracts exposing seeds

11) Harvest

11.1) Hazard Prevention

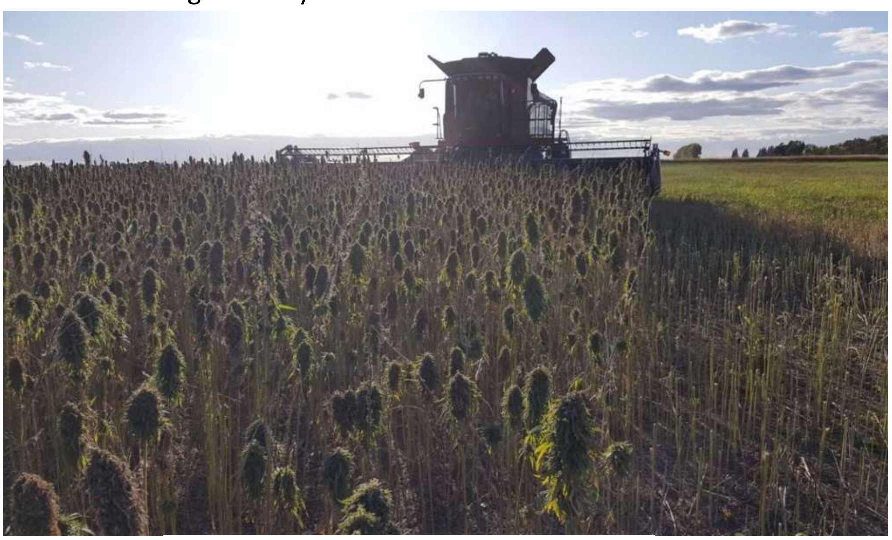
- All moving parts (feeder chains, shafts, bearings, final drives, belts, pulleys, etc.) should be monitored regularly for fiber wrapping. Wrapped fiber left unattended increases the risk of combine fires.
  - Be sure to carry several sharp pocket knives to deal with wrapped fiber
    - Inspect all moving parts regularly (hourly)
  - Straw choppers should be disabled to prevent fiber wrapping and plugging
- Harvesting hemp can cause static electricity and it is recommended to drag a chain behind the combine to ground the combine to prevent fires.
- Keep the engine compartment free of dust. The dust from hemp is oily and can combust when temperatures are hot enough.
  - Keep fire extinguishers handy!

Fiber wrapped on final drive shaft of combine

11.2) Straight Cut Combining

- Draper headers are preferred due to more even flow through the combine. This reduces slugs of material that can allow for fiber to wrap and poor grain threshing.
  - Headers with augers can allow for fiber wrapping due to additional rotating parts.
  - New knives and guards are recommended to reduce plugging of fiber.
- The header is lifted to cut the crop just below the seed head – this minimizes the amount of fiber that is ran through the combine. Remember, the least amount of fiber ran through the combine will decrease the chance of fiber wrapping.

- For uneven stands, farmers have four options for harvesting their crop:
    1. Taking smaller swaths to account for the differences in height and capture grain from all plants.
        - This is the best method for increasing yields but will take more time to harvest due to extra passes through the field.
    2. Lower the header to capture all heads from both tall and short plants.
        - This will allow for more fiber to enter the combine from taller plants and may result in more fiber wrapping.
    3. Lower the header to capture heads from all of the taller plants and some of the shorter plants.
        - This will allow for less fiber through the combine but will result in lower yields by leaving some grain in the field.
    4. Take swaths of only the tallest plants while leaving the shorter ones.
        - This allows for the most efficient way to harvest but decreases yield significantly.



Straight-cut combining industrial hemp

- Harvest speeds should allow for uniform crop flow through the machine and to prevent fiber wrapping and plugging.
    - Generally, 2 mph is a good place to start. Adjustments to speed should be based on crop conditions and combine performance.
- Equipment should be cleaned daily to avoid including spoiled grain in the next day's harvest.
- For larger acreages, begin combining at a higher grain moisture content to allow harvest to be completed before the crop becomes too mature.
    - Too dry of a crop can increase shattering and increases the potential of fiber wrapping.
- Straw choppers are recommended to be disabled to prevent fiber wrapping and plugging.
- Regularly inspect (hourly) moving parts to be sure they are free of fiber wrapping.
    - Inspect engine compartment and keep it free of dust.

11.3) Swathing

Swathing industrial hemp

- Swathing is **NOT** recommended
- Swathing can increase seed loss, increase mold and microbial contamination and increases the amount of fiber that runs through the combine (increasing risk of fiber wrapping).
- If performed:
  - Swathing should be done when dry weather is forecast for the next 3-5 days.
    - Wet weather while the grain is in the swath has a high risk of sprouting which reduces yield and quality.
  - Cut height should be at 8-12 inches off the ground and seed moistures of 15-18% should be observed.
  - Combining should begin 2-3 days after swathing to allow for some reduction in moisture in the seeds but not too much drying of the stalks.
    - If the stalks dry too much they will become very difficult to run through the combine and significantly increases the potential of fiber wrapping.

11.4) General Combine Settings

The settings below are to be used as a reference guide and consulting your machine's Owner's Manual for more specific adjustment is recommended.

Hemp seed is relatively easy to thresh and combines should initially be set to *gently thresh* the seed to avoid kernel damage.

- Cylinder Speed
  - Starting point should be similar to **Canola** settings.
  - 400-600 RPM
    - Start at lower speeds then increase based on crop conditions.
    - Higher speeds may damage seed and increase chaff going through the cleaning system.
- Concave
  - Stating point should be similar to **Canola.**
  - 1-2 inches
    - Start with wider settings then narrow if seeds are not being completely threshed from grain heads.
    - Wider settings are used for a drier crop to help reduce seed damage.
- Fan Speed
  - Fan speeds should be slightly less than settings for **Wheat**
  - 650-900 RPM
    - Start with moderate fan speeds and adjust lower if grain is being blown out the back of the combine or adjust higher if excess chaff is present in tailings auger.

        - Speeds will depend on crop conditions – higher wind speeds are required for higher moisture grain. Heavy weed pressure will also require higher wind speeds.
- Sieve/Shoe
    - Starting point should be similar to **Wheat** and slightly wider than **Canola**.
    - 0.3125 – 0.4375-inch (5/16 – 7/16) for chaffer setting
    - 0.125 – 0.25-inch (1/8 - 1/4) for shoe setting
        - Narrow chaffer sieve and/or widen shoe sieve if excess tailings are being rethreshed.
        - Narrow chaffer sieve and/or narrow shoe sieve if excess FM is entering the grain tank.
        - Widen chaffer sieve if excess grain is being lost out the back of the combine.
- Rotor Speed
    - Starting point should be similar to **Canola**
    - 350-500 RPM for 17-25% moisture
        - Start at lower speeds and increase based on crop conditions.
            - Faster speeds can be used for crops with lower moistures.
    - The pitch of the flow bars should be set to the maximum slope to move fiber through the combine as fast as possible.
- Rotor Concaves
    - Best results occur when **Wheat** concaves are used in the front and **Slotted** concaves are used in the rear of the rotor cage.

- Conventional and single rotary combines are preferred. Dual rotary combines are less desirable due to the increased risk of fiber wrapping and plugging of the opposing rotors.
    - Some older rotary combines allow material to enter the middle of the rotor rather than the bottom of the rotor (new models).
        - Material entering the middle of the rotor increases the potential for fiber wrapping, especially on the front bearing.

11.5) <u>Troubleshooting</u>

- Be sure to only adjust ONE setting at a time to determine the result of the adjustment.
- **Seeds are being lost through the back of the combine**
    - Adjust Ground Speed
        - Speed is too fast and too much material may be entering the combine for proper removal of grain.
        - Speed is too slow to allow for even flow of material and grain slugs keep happening.
    - Adjust Threshing Speed
        - Increase threshing speed if seeds are not completely separated from grain heads.

- Adjust Concave Setting
  - Concaves may be set too wide. Narrow setting until seed is removed from heads but is not being cracked.
- Adjust Fan Speed
  - Reduce fan speed – fan speed may be too high and blowing seeds over the sieves and out the back of the combine.
- Adjust Sieve Setting
  - Widen chaffer sieve if excess grain is being lost out the back of the combine.

- **Seeds are Cracking**
  - Adjust Threshing Speed
    - Reduce threshing speeds until seeds are no longer being cracked.
  - Adjust the Concave Setting
    - Concaves may be set too narrow. Widen setting until seed is no longer cracking but is being completely removed from grain head.
- **Too Much Tailings for Rethreshing**
  - Adjust Fan Speed
    - Increase Fan Speed – fan speed may be too low allowing for more chaff material to enter on to the Chaffer Sieve.
  - Adjust Sieve Settings
    - Narrow the Chaffer Sieve – sieve may be too wide and overloading the lower sieve allowing excess tailings.
      - Too narrow setting may allow for more FM in the grain tank.
- **Excess FM in Grain Tank**
  - Adjust Flow of Material through the Combine
    - Adjust Ground Speed and/or Header
      - Adjust ground speed and/or header to provide even flow of material through the combine. Grain slugs can overload the threshing and separating components leading to increased FM in the grain tank.
        - Even flow can be determined by observing windrows behind the combine. Even windrows are results of even flow of material while bunched windrows are results of slugs of material going through the combine.
  - Adjust Threshing Speeds
    - Reduce Threshing Speeds – higher threshing speeds increases chaff material that can overload sieves and can end up in the grain tank.
  - Adjust Fan Speed
    - Increase Fan Speed – fan speed may be too low for current chaffer sieve setting and current ground speed.
  - Adjust Sieves
    - Narrow chaffer sieve and/or narrow shoe sieve if excess FM is entering the grain tank.

12) Post-Harvest

12.1) Handling

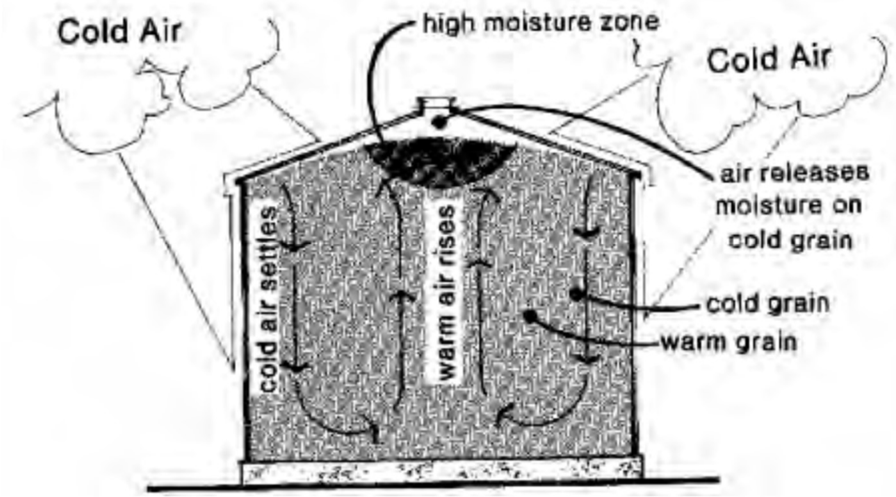

Grain being loaded in to trailer

- Hemp seeds can be easily damaged, resulting in decreased seed quality. Damaged seed hulls are at higher risk of rancidity. Seed should be handled as few of times as possible and done so as gently as possible.
    - Rancid grain is subject to rejection.
- When unloading combines, reduce unloading speeds
    - Avoid unloading on-the-go.
- Conveyors are preferred but augers will work.
    - If using grain augers, keep augers full and run them at slow speeds (idle).
        - Larger diameter augers (10-12 inch) work better than smaller diameter augers (6-8 inch).
- Grain samples should be collected as the grain goes in to the bin.

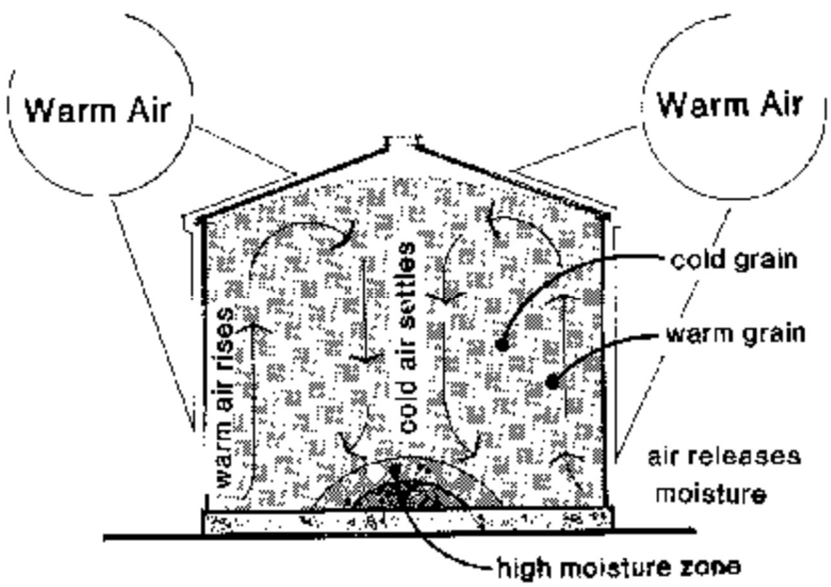
12.2) Grain Storage

- Hemp seed must be properly dried to preserve grain quality. Heated or moldy grain will result in rejection for use in the food markets. Monitoring regularly (daily) while grain is drying is recommended.
- Hemp seed can heat rapidly (3-6 hours) after combining, depending on moisture content. Due to the rapid heating, grain should be put under aeration immediately to avoid overheating.
    - DO NOT LEAVE HARVESTED GRAIN SIT OVERNIGHT WITHOUT AERATION
- During the early stages of heating, seeds stick together and form lumps. This will lead to a rapid increase in free fatty acid content of the oil resulting in lower oil quality. Heating will lead to mold growth and possibly scorching (discoloration) of the seed.
- Final moisture of grain should be at 9% for storage.
    - Properly dried grain will store for 1-2 years without loss of food quality.
- When choosing the proper storage system for hemp, priority should be given to cleanliness, handling, conditioning and aeration capabilities.
    - Hopper bins with aeration are the best choice
    - Flat metal bins with aeration floors are the second choice
- Dried grain can lose condition due to the inability to control the temperature of the grain. Improper temperature control inside the bin causes moisture to move from one part of the grain mass to another (moisture migration) – this causes moisture to accumulate and allow grain to spoil.
    - In the fall, when air temperatures decrease, grain along the bin wall cools down faster than grain in the middle of the bin. The temperature difference allows air to move down the bin wall and towards the center of the bin. As the air moves through the grain

it becomes warmer and begins to pick up moisture from the grain. Once the warm, moist air hits the cool upper surface of the grain, condensation occurs. Moisture will concentrate on the sides of the bin and the cone at the top during fall and winter. Flattening the cone will help to prevent moisture buildup. (see image below)



- In the spring, the moisture migration is reversed. The warming sun on the outside of the bin causes moisture currents to move up the bin walls and then down the center of the bin. Moisture condensation occurs at the center of the bottom of the bin. (see image below)



- Good aeration and rotating the grain can help minimize moisture migration and grain spoilage.
  - Minimum rotation should occur when the seasons change (fall to winter, winter to spring).

12.3) Aeration

- Air moves fairly easily through hemp grain and therefore full floor aeration or rocket systems in hopper bins are best suited to cool and dry hemp grain.
- Aeration for 1-3 weeks is required to dry grain, depending on air temperature, humidity as well as grain moisture.
  - High capacity fans are preferred to reduce moisture as quickly as possible.
- Artificial heat may be necessary if ambient conditions are unfavorable. Heat of 120°F or less should be observed since overheating can discolor seeds which may be subject to rejection.
  - Continuous flow driers are preferred over batch driers due to the increased risk of hot spots in batch driers.
  - Hopper bins with 5-10 HP fans with 100,000 BTU propane burner is one of the best options to dry hemp grain.
    - Fan size (or number of fans) should be properly matched with the size of the bin.
- It is recommended not to overfill aeration bins since the grain may heat before it is dried and cooled to safe storage conditions.
  - Aeration bins should be filled to 50% capacity when grain moisture is below 20%
  - Aeration bins should be filled to 30% capacity when grain moisture is above 20%
  - Rotating grain 1-3 times may be necessary to avoid hot spots in the bin.
    - If grain moisture is above 25%, grain should be rotated within the first 24 hours
    - If grain moisture is below 25%, grain should be rotated within the first 24-48 hours
- Monitoring grain regularly for the first 6 weeks of storage is critical to avoid issues with heating.

12.4) Cleaning

Grain cleaning before grain enters storage bin

- Hemp grain will likely be cleaned 2-3 times, depending on how well the combine is able to clean the grain at harvest.
  - The first cleaning should occur immediately after harvesting and prior to storage.
  - The last cleaning should occur before grain is shipped to the processor. This cleaning will size and clean the grain to 99.9% purity.
    - Many processors try to meet Gluten Free status and require the grain to be cleaned extensively.

13) Fiber Harvest

- Fiber production of X-59 has been documented to produce – 0.89 – 2.69 tons/acre.
- Standing residue from straight cut combined hemp should be cut within 1-3 days after combining to avoid fiber wrapping.
    - Be cautious of using discbines – the rotating discs may allow for opportunities of fiber wrapping. It is recommended to cut a few feet and check to see if any wrapping has occurred.
        - Check periodically for fiber wrapping.
    - Cutting can also be left until the following spring after some decay has occurred.
        - This allows for easier harvest and handling.
- Stalk moisture of 15% or less should be maintained for baling. Achievement of this moisture may occur 7-21 days after cutting, depending on weather conditions.
- It is recommended to till fiber residue the following spring to allow for some decay of the fibers. This allows for easier tillage and reduced fiber wrapping.
    - Moldboard or chisel plowing may allow for fall tillage to occur without many issues due to fewer moving parts.

Round baling industrial hemp fiber

Additional Resources

- Industrial Hemp Harvest and Storage – Best Management Practices (Alberta)
  https://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/crop15539/$file/HempHarvestStorage.pdf?OpenElement
- Alberta Agriculture and Forestry – Specialty Crops – Industrial Hemp
  https://www.agriculture.alberta.ca/app21/infopage?cat1=Crops&cat2=Special%20Crops
- Canadian Hemp Trade Alliance (eGuide)
  http://www.hemptrade.ca/eguide
- Kuchar High Performance Combine Parts
    - https://www.kucharcombineparts.com/
    - Ph: 217-854-9838