New Jersey Commercial Hemp Field Production Guide

RUTGERS
New Jersey Agricultural Experiment Station

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PREFACE

This recommendation guide is not intended for use by home gardeners. The information provided is intended for farm-scale, commercial field production of hemp.

Hemp is a regulated crop that requires permits to be grown/handled and processed.

Trade Names or Brand Names:

The trade or brand names given herein are supplied with the understanding that no discrimination is intended and no endorsement by Rutgers Cooperative Extension is implied.

DISCLAIMER:

Laws and regulations for hemp in NJ and elsewhere are subject to change. Please refer to the most current state and federal regulations regarding the growth, processing and handling of hemp. This guide is intended to provide guidance for producing a hemp crop and is not a legal document.

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HISTORY OF HEMP

Hemp (*Cannabis sativa* L.) has a long history with human civilization and is believed to be among the first plants cultivated by humans. *Cannabis sativa* L. originated in Central Asia and has been utilized for multiple products from the time it was domesticated between 4,000-6,000 years ago in China. By the 1600's hemp was widely grown in Europe for fiber and grain and was used mainly for cordage and cloth for sails and other fabrics (Fortenberry and Bennett, 2001). Hemp was brought to what is now the United States early during the migration of the Puritans and was primarily grown in Virginia, Pennsylvania, and other regions to produce cordage and fabric for sails and the marine industry. Hemp production for fiber was prolific in the early colonial period and was promoted as a viable crop by George Washington, Benjamin Franklin, and Thomas Jefferson (Roulac, 1997). It has been rumored that the first drafts of the Declaration of Independence were drafted on hemp paper. The industry quickly expanded in the U.S., resulting in more than 160 factories and thousands of employees throughout the Midwest (Roulac, 1997). There were also several hemp seed oil mills that pressed hemp seed into oil, which was used in paints, ink, lamp oil and other products.

In the mid 1800's, hemp production gradually declined in response to several factors including the industrial revolution, the mechanization of cotton processing and innovations in the marine industry resulting in reduced demand for cordage and fiber. The hemp industry continued to decline through the early 1900's as other crops were favored due to their post-processing characteristics.

In 1937, the federal Marijuana Tax Act placed Cannabis production and sales under the control of the U.S. Treasury Department which levied significant taxes on the sale and distribution of hemp and all other cannabis products regardless of THC level. During World War II, hemp production was promoted due to a shortage of other natural fibers (Marcus and Small, 2014). The "Hemp for Victory" campaign lifted the ban on U.S. hemp production and promoted production to aid in the war effort resulting in a short-term revival of domestic hemp

production. In 1970 the Controlled Substance Act Classified Cannabis sativa as an illegal Schedule I drug making all cannabis production illegal without a DEA permit.

The 2014 Farm Bill paved the way for domestic production of hemp (Johnson, 2018). The 2018 Farm Bill directed the United States Department of Agriculture USDA to establish a national regulatory framework for hemp production in the United States. These rules were completed in early 2021 and took effect on March 22, 2021. The New Jersey Hemp Farming Act was enacted in August 2019. This new legislation complies with the 2018 Farm Bill and provides the regulatory framework that allows hemp producers to grow and sell hemp for commercial purposes in New Jersey. On December 27, 2019, New Jersey was among the first three states to have its Hemp Program approved by the USDA. These regulations are enforced by the New Jersey Department of Agriculture Hemp Program.

There is renewed interest from producers related to the feasibility of hemp production in New Jersey as it is grown for a wide variety of consumer and industrial products (Cherney and Small, 2016). Industrial hemp may represent a new crop and market opportunity for New Jersey farmers. Additionally, industrial hemp may fit nicely with existing crop rotation practices with other field crops. Although there is much interest and speculation related to hemp production, there has been limited research conducted in the northeastern United States and none in New Jersey to quantify the feasibility of hemp production in the state.

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Small, E., and D. Marcus, "Hemp: A New Crop with New Uses for North America," in Trends in New Crops and New Uses, ed. J. Janick and A. Whipkey, 284–326 (Alexandria, VA, ASHS Press, 2002).

Fortenberry, T.R., and Bennett, M. 2001. Is Industrial Hemp Worth Further Study in the U.S? A Survey of Literature. Staff Paper No. 443.

HEMP REGULATORY COMPLIANCE

For further information about the New Jersey Hemp Program
email NJHemp@ag.nj.gov or call 609-406-6941.

Introduction

Unlike many other commodities grown in New Jersey, hemp production is strictly regulated by the New Jersey Department of Agriculture, Division of Plant Industry, under the authority granted by the federal and state government. It is critical that producers understand and comply with these regulations to ensure the legal production, sale, and distribution of hemp or hemp products in New Jersey.

Federal Regulations

The Agriculture Improvement Act (2018 Farm Bill) establishes regulations to implement the legal production of hemp provided that the crop is grown in compliance with a state program or, in the absence of a program, under the federal USDA program. These regulations essentially remove hemp as a schedule 1 drug provided that any part of the plant grown has a delta-9 THC (**T**etra**h**ydro**c**annabinol) concentration of not more than 0.3 percent on a dry matter basis. Any plant material with a THC concentration above 0.3 percent is still considered marijuana and is currently still illegal under federal law.

Summary

The New Jersey Department of Agriculture promulgated new rules regulating the cultivation of industrial hemp, “hemp”, in the state. The New Jersey Department of Agriculture is responsible for regulating hemp production in the state. The New Jersey Hemp Farming Act (N.J.A.C. 2:25-1) was enacted in August 2019. This legislation complies with the 2018 Farm Bill, which authorized hemp producers in the US to grow and sell hemp for commercial purposes. The NJ Hemp Farming Act established the New Jersey Hemp Program administered by the Division of Plant Industry within the NJ Department of Agriculture (NJDA). The objective of the Program is to provide licenses for growing, processing, and handling hemp pursuant to the New Jersey Hemp Farming Act, and the 2018 Farm Bill. On December 27, 2019, New Jersey had its Hemp Program approved by the USDA. Any state seeking to have primary regulatory authority over hemp production must receive USDA approval of its program. The USDA’s regulations specify provisions that are required in state hemp production plans, including procedures for sampling and testing, disposal of noncompliant hemp, enforcement, inspection, and reporting.

Accordingly, the NJDA has established a USDA approved hemp licensing program to promote the cultivation and processing of hemp, develop new commercial markets for farmers and businesses through the sale of hemp products; and promote the expansion of the State's hemp industry to the maximum extent permitted under federal law.

Program Overview

The NJ Program establishes reporting requirements throughout the growing season, including pre-planting reports, planting reports, pre-harvest reports, and an annual production report. In addition, producers are required to report hemp crop acreage and other relevant information to the USDA Farm Service Agency. The New Jersey program also establishes procedures for sampling and testing hemp. Fifteen (15) days prior to the anticipated harvest date, an inspector from the Department or a DEA registered third-party lab will collect samples to test for compliance with the federally defined THC level for hemp. All results are subject to review by the Department which is authorized to re-test and collect samples as necessary to ensure compliance. THC testing procedures must use approved laboratory procedures. Furthermore, hemp producers must grant entry to the Department onto premises where hemp is grown, processed, or handled for inspection purposes. In addition to individual sampling and testing requirements, the Department will also conduct an annual inspection of, at a minimum, a random sample of hemp producers.

To comply with this federal requirement, all key participants involved in a hemp production operation must pass a criminal background check by the New Jersey State Police.

It is the participant's responsibility to ensure that the transfer or sale of any hemp material complies with all applicable state and federal laws. All hemp materials must be appropriately identified or labeled during transit.

Overview of the New Jersey Hemp Licensing Process

Hemp Grower License

Anyone growing hemp New Jersey must successfully complete the full application process with the New Jersey Department of Agriculture (NJDA) and sign a Grower Licensing Application before taking possession of any viable hemp seeds/ propagules or in-program harvested hemp materials. Eligible applicants include an individual, business, producers, higher education institution, and others as designated by the rule. This license must be completed annually at least 30 days prior to planting, handling, or processing hemp. All applications must contain the following information:

a. The name and address of the applicant.
b. The business name, type of entity and employer identification number.
c. The legal description of the property.
d. The geospatial location (GPS location provided in Degrees Decimal Minutes *ex: lat: 38° 9.919'N, long: 84° 49.267'W*).
e. A map of the area where the applicant plans to grow or process hemp.
f. A criminal background check from the New Jersey State Police for the applicant and any key participants.
g. A $50 annual application fee.

In addition to the annual application fee, the following (current) licensing fees apply depending on the type of license applied for:

Growers……..$300.00 fee. (plus $15 per acre)
Processors……..$450.00
Grain/Fiber Processors.$1,000.00
Handlers……..$450.00

*Hemp growers who process or handle their own hemp are not required to pay additional fees. If a grower processes or handles hemp grown from at least one separate hemp producer, that grower shall pay processing or handling licensing fees, as applicable.

*Processors who produce multiple types of hemp products shall determine their annual fee based on the sum from the fee schedule. For example, a hemp producer who processes grain ($450.00), and CBD extracts ($1,000), will pay a total licensing fee for the year of $1,450. Processors and handlers are also required to be licensed. The Processor and Handlers license applications are also acquired through the NJDA.

Terms and Conditions of Licensure

The license is valid for one year from the effective date of issue and is subject to several terms and conditions. It is the responsibility of the license holder to understand and comply with these terms and conditions. See N.J.A.C. 2:25-2.2 for a complete explanation.

Domestic Seed/Propagule Request Requirements

The NJ hemp program establishes rules and procedures for acquiring seeds and plant material to be grown in the state for grain, fiber, oil, and CBD production. These rules are enacted to reduce the potential for losses from noncompliant hemp production, to ensure the integrity of the NJ hemp program and to minimize financial implications for producers.

Compliance with Federal THC Limit

License holders must use only seed, propagules, or plants that are demonstrated to conform to the 0.3% delta-9-THC limit. Documentation of measured THC levels shall be submitted to NJDA with this request. Documentation shall also include the name, address, email, and telephone number of both the lab, and the seed source. Any license holder found using seed, propagules, or plants not reviewed and approved by the NJDA may be subject to revocation of the Licensing Agreement in addition to any civil or criminal liabilities that may exist.

Intellectual Property

License holders are prohibited from growing for replication any intellectual property or genetic lines for which they do not have a license or written permission from the property owner.

Domestic Seed and/or Plant Acquisition (from within the United States)

All seed and/or plants sourced from within the United States, but outside of New Jersey, must be preapproved by the NJDA. License holders shall submit the Domestic Seed/Propagule Request form to NJDA at least three (3) weeks in advance of any proposed transfer of materials.

The seed and/or propagule source must be a participant in a "duly recognized Hemp Program." It is the license holder's responsibility to ensure that the transfer or sale of any hemp material from another program complies with all applicable laws and policies in the originating state.

Prohibited Varieties

The NJDA hemp program maintains a list of varieties grown in New Jersey with total potential delta- 9 THC test result of above 0.3%. Producers should review this list of hemp varieties before sourcing, purchasing, and acquiring the hemp seed, clones, propagules or cuttings which they will be growing to ensure that they comply with all the requirements of the New Jersey Hemp Program.

The hemp varieties on this listing are categorized as Prohibited Varieties or Varieties of Concern.

New Jersey Varieties of Concern

Auto CBD, Bee, Boax, Bubba Kush, Cherry Abacus 2.0, Cherry HD, Cherrywine, Early Abacus, Eclipse, Elektra, Franklin, Merlot, Mountain Mango, OT, Purple Kush, Quick Kush, Remedy, T-Bird, T1-Trump, Ultra Nevada, Wife, Work Horse, Hawaiian Haze, Frosted Lime, Special Sauce.

New Jersey Prohibited Varieties:

Blue Genius, Terptown, Haute Wife, Black Cherry, Cherry #5, Sour Space Candy, Suver Haze, Lifter, Otto II Stout

Reporting Requirements

The NJ hemp program establishes reporting requirements throughout the growing season. In addition, producers are required to report hemp crop acreage and other relevant information to the USDA Farm Service Agency. The reports will ensure that accurate legal descriptions of land and quantities of hemp are maintained and ensure that all hemp is produced in compliance with state regulations or is destroyed.

Annual Reporting

Pre-Planting Report

All hemp producers shall file a Pre-Planting Report at least five days prior to planting that includes:

1. Verification that the hemp producer has reasonable grounds to believe that the crop planted is of a variety that will produce a delta-9 THC concentration of no more than 0.3 percent on a dry weight basis. In some instances, a Certificate of Inspection COI may be required.
2. A description of the cannabis varieties, including hemp, to be planted.
3. A statement of intended end use for all parts of any cannabis plants, including hemp, grown within a licensed area; and
4. The name and location of any hemp processing plant to be utilized.

* The hemp producer shall not plant hemp in any form until the Pre-Planting Report has been approved by the Department.

Planting Report

Due to the NJDA within 10 days after planting and/or 10 days after emergence of any volunteer hemp plants in a licensed area that includes:

1. A list or description of all varieties of hemp planted, or of volunteer hemp plants that have emerged and are not destroyed.
2. A description of the planting location, including an updated map, acreage, or square feet of each variety of hemp planted, or of volunteer hemp plants that have emerged and are not destroyed, the intended use of the plant and the anticipated harvest date.

Harvest/Disposal Report

At least 30 days prior to harvest, each producer shall file a Harvest/Disposal Report that includes:

1. Documentation that the hemp producer has entered into a purchase agreement with a licensed hemp processor either in this State or under a USDA-approved hemp program or an explanation of the disposal or destruction of the crop.
2. The harvest date(s) and location of each variety of hemp grown in a licensed area or an indication of the destruction of the crop.

* If the crop has been grown for floral production, the producer may not comingle the crop until an approved test result is obtained indicating acceptable THC test results.

Production Report

All producers shall submit a completed Production Report form about the prior year's production on or before December 1 annually. The Production Report shall include:

1. The number of acres or square feet planted.
2. Varieties planted;
3. Production methods;
4. Production inputs/yields;
5. Any other information requested by the Department.

USES FOR HEMP

Although industrial hemp and marijuana are botanically from the same species of plant, *Cannabis sativa* many different cultivars or varieties have been developed with distinctly different end-uses. The ultimate end-use results in plants with different chemical composition and growth habit, as well as varied production systems and other management strategies and will have a significant impact on variety selection.

Humans have cultivated hemp for thousands of years for many uses. The earliest use of hemp has been reported to as early as 4,500 B.C. when China became the first to use hemp as a crop grown for various uses including scrolls, netting and as a food source. Throughout the subsequent generations, hemp has been used in Europe and later the United States both as a source of fiber for the development of many textiles, rope and paper products, and as a source of seed for oil and food production. Hemp cordage later became an important use of hemp fiber during World War II in response to world textile fiber supply shortages. Today the hemp industry continues to develop as restrictions on production have been lifted and in response to consumer interest and demand for a diverse pool of cannabis products. In general hemp is grown for fiber production, seed production, cannabinoid CBD production, or in some cases as a dual-use crop (often fiber and seed). The uses for hemp products have been reported to consist of more than 25,000 products ranging from textiles to health supplements. In recent years the demand for CBD products has increased dramatically resulting in significant interest from producers in the northeastern United States.

Fiber Production

Certain varieties of hemp are grown for their fiber content. Fiber is harvested from the stalks of hemp fiber varieties and consists of long bast fibers (2-25 mm) and shorter hurd fibers. The bast fibers are a higher-quality fiber found in the portion of the stalk. These long fibers are hollow inside and are very strong making them ideal fibers for various products including high quality paper, fabrics and textiles, cordage, insulation, and carpeting. The shorter hurd fibers have a higher lignin content and are woodier than the bast fibers making them ideal for use in the production of materials such as fiberboard, paper additives, animal bedding and as additives in plastics, spill absorbents, mortar and fiber board. Hemp fibers are also being used as components in building materials such as hempcrete and as a replacement for synthetic fiber composite in automobile interiors, making hemp fiber production a potentially environmentally friendly cheaper natural alternative to other fibers. According to an article reported by the

hemp Industry Association, hemp fibers may also be a catalyst for biofuels and other important bioproducts.

Seed Production

Hemp seeds are produced for various uses and have been cultivated for thousands of years. Hemp seed has many reported benefits as a dietary supplement for both humans and livestock (Callaway, 2004; Carus, 2017). Hemp seeds contain many of the essential amino acids required for human nutrition and are a source of antioxidants, essential nutrients and are high in protein content, fiber and fats. The nutritional content of hemp seeds makes it a component in many consumer products including flours, meals, coffees, and toasted seed products. Although not currently legal as a livestock feed in the United States, it is used as a feed in other countries and has been investigated as a potential feedstock in livestock production in the U.S. Hemp seeds are also a component in fish and bird foods and are also used in cosmetic and personal health products. Hemp seed is perhaps best known for having a high oil content and is often grown for processing and is often used as a conventional cooking oil alternative due to its oil quality. After hemp seed is crushed for its oil content, the meal (seed cake) can be used as a component of many products or as a feed biproduct. As hemp production increases, more secondary or tertiary uses will be developed for hemp seed and seed cake.

Hemp for Floral/CBD Production

In recent years there has been increased interest in hemp production for CBD/CBG and other secondary compounds for use in various products. These molecules are reported to have various potentially beneficial impacts on humans. To be classified as hemp, harvested plant material must contain less than .03% THC. These compounds are concentrated in female flower buds and other parts of the plant and have many reported uses ranging from pain management to general wellness products. Floral products represent a significant portion of the demand for hemp, estimated to be more than $1 billion in 2022. Products containing floral components of hemp range from pharmaceutical supplements, such as tinctures, teas, and oils, to wellness products including drinks, candies, rubs and salves. Although much of the demand for hemp production in the northeast is driven by the floral market, the FDA has not determined that floral products are safe for use in food production in human or animal foods.

Fiber	Grain/Seeds	Floral/ CBD
• Textiles • Rope • Paper/pulp products • Yarn/fabric • Building materials • Composite materials • Biofuel	• Oils • Animal feeds • Bird seed • Flours • Seed cakes • Soaps • Personal hygiene products	• Health supplements • Pain management • Teas • Gummies/candies • Tinctures • Salves/rubs

Resources:

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VARIETY SELECTION

Proper variety selection is a critical step in successful hemp production. As such, growers should ensure that they are selecting varieties that are suited for their growing conditions, legal to grow in their state, and suitable for the end-use of the crop.

Selecting the Best Variety for Growing Conditions

One of the most important considerations for successful hemp production is selecting varieties that are suitable for the region. Factors to consider include growing degree days, disease resistance, weed resistance and competition, tolerance to soil moisture and many others. Field conditions may also be an important consideration when selecting the best variety and type for field production. Hemp grows best on a loose, well-aerated loam soil, with high fertility, abundant organic matter (> 2%), and a pH of 6.0–7.5. Well-drained soils are best, as poorly drained, heavy textured soils, or poorly structured soils often result in stand establishment failures. Reports indicate seedlings and young plants are prone to damping-off, resulting in poor stands. Sandy soils can produce hemp with adequate irrigation and fertilization, but these additional costs will need to be evaluated with respect to production economics.

Many hemp cultivars are photoperiod sensitive, and flowering is initiated in response to shorter periods of sunlight. As a result, it is important to select varieties that will reach maturity during the suitable growing period in your area. Contact Rutgers Cooperative Extension for more information regarding variety selection. Currently, Rutgers Cooperative Extension does not recommend specific varieties and does not maintain a list of varieties for production in the state of New Jersey. More research is needed over multiple seasons to determine the best varieties for the State.

Selecting Varieties Based on End-Use

Several factors should be considered when selecting the proper variety. Growers should carefully consider varieties based on the final plant part/parts to be harvested. For example, varieties bred primarily for grain production can have significantly different maturity dates which would require different planting dates for maximum yield and quality. Varieties developed for specific end-uses may also have varying physical attributes, such as seed size, test weights and germination percentages, all which may result in significantly different production practices. For example, fiber varieties are often taller and planted at higher seeding

rates per acre to promote fiber yield, while grain varieties and floral varieties are often shorter and more branching. Producers growing hemp for CBD production or for dual-use production systems will likely require different varieties to maximize yields and other quality characteristics.

As we begin to have more experience with hemp production, we are learning that varieties are regionally specific. Farmers looking to enter the industrial hemp market for the first time will need to understand varietal options that are available in their region and carefully determine which hemp variety is most suitable to their production and marketing strategies.

Selecting Varieties Based on Regulatory Compliance

One of the most unique aspects of hemp production is the importance of producing a crop that is harvested within the regulatory limits for THC. Unlike many other commodities grown in New Jersey, hemp production is strictly regulated by the New Jersey Department of Agriculture, Division of Plant Industry, under the authority granted by the federal and state government. It is critical that producers understand and comply with these regulations to ensure the legal production, sale, and distribution of hemp products grown in New Jersey. According to New Jersey regulation, license holders must use only seed, propagules, or plants that are demonstrated to conform to the 0.3% delta-9-THC limit. The NJDA hemp program maintains a list of varieties grown in New Jersey with total potential delta-9 THC test result of above 0.3%. Producers should review this list of hemp varieties before sourcing, purchasing, and acquiring the hemp seed, clones, propagules or cuttings which they will be growing to ensure that they comply with all the requirements of the New Jersey Hemp Program.

Growers should also consider other factors when selecting a variety to plant including yield, quality and marketability of the end-use product.

HEMP SOIL FERTILITY AND SOIL pH

Hemp is most successful if grown in loose, well-aerated, loam soils. In addition, the soil should have adequate fertility and an abundance of organic matter (> 2%). In NJ, most soils are mineral soils and maintaining high organic matter is a challenge, especially with tillage. The first step is to test for soil pH and fertility levels. Once results are in-hand, make adjustments to bring soil pH and fertility levels as close to optimum as possible. The better your soil is prepared before planting, the greater the chance of producing a successful crop. Typical best management practices (BMPs) for soil husbandry include a good soil management program, proper liming and fertilization, good tillage practices, crop rotation, annual additions of organic matter, and adequate irrigation. Using cover crops between cash crop plantings is one of the easiest and most economic ways to increase soil organic matter. Cover cropping aids in maintaining good soil structure and helps to retain topsoil that may be lost through water or wind erosion. Another benefit of cover cropping that may be overlooked is increased soil system biological diversity. By promoting diversity in the living part of soil managing other issues like soil borne diseases, weeds, and nematodes can be accomplished by creating healthy soils.

Soil Tests:

The best way to determine the lime and fertilizer needs of your soil is to have it tested. Soil testing should be performed every 1 to 3 years. The Rutgers Soil Testing Laboratory (See information in appendices) or other labs can test soil for pH, macro nutrient fertility levels, micronutrient fertility levels, organic matter levels, soluble salts, cation exchange capacity, texture and other specialized analysis. If you do not know the present fertility level of the soil in a field, your application rates of lime and fertilizer materials will most likely be incorrect. Taking a scientific approach minimizes potential for plant damage, reduces water pollution potential, and can save money. Lime and fertilizer recommendations from soil testing laboratories are based on soil test results, the crop to be grown, past cropping, past liming, and fertilization practices. This is information must be supplied on the soil sample questionnaire when submitting the sample. For this reason, it is particularly important to supply accurate information about the history and future use of the field along with the soil sample.

Liming and pH:

Most soils in the Mid-Atlantic region, including New Jersey, are naturally acidic or become acidic under crop production systems and with rainfall. If soils become too acidic (generally pH less than 6.0), crop performance is hindered by many factors, including reduced availability of plant nutrients. A regular liming program is required to neutralize soil acidity and to supply crops with calcium and magnesium. The first step in a liming program is knowing the optimum or target value of the crop to be grown. Many crops will grow over a wide range of soil pH, but hemp performs best in soils in the 6.0-7.0 range. Soil pH alone cannot be used to determine the amount of liming material needed to adjust soil ph. Soil test results provide the data needed (i.e., soil texture) to determine the lime requirement and type of lime to apply.

Liming materials neutralize soil acidity, supply calcium (Ca) and supply or increase available magnesium (Mg). Selection of the appropriate liming material based on its Ca and Mg concentrations is a key to furnishing crops and soils with sufficient amounts of these much needed nutrients. The goal of a liming program is to establish the desired soil pH and to maintain the soil fertility levels for Mg and Ca in the optimum range. Fine particle sized liming materials are recommended when soils need rapid neutralization of acidity. Medium and coarse-sized liming materials are best suited for maintenance of soil pH once the desired soil pH range has been attained using fine-sized liming material. When soil pH is low, soil test levels of Ca and Mg may be below optimum levels or deficient. It is important to choose a liming material that contains a significant concentration of Mg; these liming materials are commonly referred to as dolomitic type or dolomite. If the soil Mg level is below optimum-very low or -low, it is recommended to use a liming material that has a minimum concentration of 9% Mg. If the soil Mg level is below optimum -medium, use a dolomitic liming material that has 3.6 to 9% Mg. If the soil Mg level is optimum or above optimum or exceeds crop needs, use a calcitic or calcite liming material that has less than 3.6% Mg.

Occasionally soils test below optimum or deficient in Mg or Ca, but do not need lime for pH adjustment. For soils needing Mg, apply Epsom salt (9.9% Mg) or sulfate of potash magnesia (21.8% Mg). If soil pH is appropriate for the crop, but the soil test Mg level is below optimum-very low, apply 30 lb/A of Mg from a Mg fertilizer. If Mg is below optimum-low, apply 15 lb/A of Mg. If soil pH is satisfactory for the crop, but the Ca level is below optimum--very low, apply 350 lb/A of Ca (=1500 lb/A of gypsum). If the pH is satisfactory, but Ca is below optimum--low, apply 175 lb/A of Ca (=750 lb/A of gypsum).

The soil test report will often contain recommendations for pH and fertility adjustments to soil. If not contact your local Rutgers Cooperative Extension County Agricultural Agent for recommendations.

When to Apply Lime

Lime is slow to react in soil. It may take up to 6 or more months after lime application for soil pH to reach desired levels. Therefore, apply lime well ahead of planting. Lime can be applied at any time of the year and should be done when a crop is not present to allow for mixing into the topsoil. Applying lime in fall allows for the lime to react in the soil prior to the start of the next growing season. It is especially important to have your soil pH adjusted to the correct level when using mulches. Once plastic mulch is laid or crop is established, it is virtually impossible to correct a soil pH problem using surface applications of lime. Soils naturally become more acidic over time. The frequency of prescribed lime application varies with soil characteristics, cropping system, and fertilizer practice. Heavy use of ammonium and urea N fertilizers accelerates soil acidification. Test soil pH every 1 to 3 years and readjust soil pH to the desired range to avoid excess acidity.

How to Apply Lime

Lime is most effective when spread uniformly over the soil surface and thoroughly mixed with the soil by plowing, disking, and harrowing. If needing to apply large amounts of lime, it is best to use split applications. Apply half the lime and plow it under and then apply the other half to the plowed surface and disk it into the soil as deeply as possible and especially as deep as the root zone for the intended crop.

Fertility:

Major Nutrients

Nitrogen

Nitrogen (N) plays a significant role in crop nutrition and yield and is considered the most crucial nutrient in hemp production. Nitrogen fertilization amounts for hemp production are also influenced by the end use. Application of N fertilizers positively affect hemp's plant height, biomass for fiber hemp varieties, and grain and protein content for seed yielding varieties. The

N requirement is high during the first one month of hemp growth. Therefore, N is usually applied at planting, in most cases.

Some research shows, beyond N fertilization rates of 134 lb/A, no further yield increase was reported. Excess N application stimulates rapid stem elongation which makes the hemp crop more susceptible to lodging. Inadequate N, on the other hand, will cause loss of yield, while excess N will reduce the fiber quality. Hemp growth response to fertilizer N was negligible in soils already rich in N. N fertilization cannot be accurately determined from literature data and therefore warrants more investigation. More research is needed to evaluate the effect of an application on the yield of fiber, seed, and CBD hemp varieties under field conditions.

Phosphorus

Phosphorous (P) is an essential nutrient throughout all hemp growth stages. However, its demand gradually increases as the plant matures. P is also essential during the early growth stages of hemp as it plays a major role in plant strength, root development, and resistance against pests. P application has been found to increase plant height in hemp, but its effects on hemp biomass and seed yields were inconsistent. Hemp plants suffering from P deficiency show visual symptoms including stunted growth and development of reddish-purple color in the leaf due to anthocyanin pigment formation. More research is needed on P fertility in field grown hemp.

Potassium

Hemp is less responsive to potassium (K) compared to N and P fertilization, and very few experiments evaluating the effect of K on hemp have been conducted. K uptake increases as the crop grows which is similar to trends observed for P. However, in the case of fiber hemp varieties, the peak uptake occurs during fiber developmental stages.

Other Nutrients

Magnesium

Hemp plants need a relatively substantial amount of magnesium (Mg) and are very sensitive to Mg deficiency. Mg-deficient hemp plants are characterized by dark green younger leaves, grayish-white patches in older leaves due to loss of chlorophyll and slowed root and shoot development. An imbalance of magnesium and calcium in the plant can induce deficiency

symptoms of one or the other nutrients. For this reason, it is important to have these two nutrients in balance and at optimum levels, to be shown on soil test results.

Calcium

Hemp, like other crops, needs adequate levels of calcium since it plays a crucial role in determining the structural rigidity of the plant cell wall. Calcium is considered an immobile nutrient. The reason for that is due to the element being "locked-up" and not able to be translocated to other areas of the plant. Calcium taken up in the roots, will move upwards in the plant and will accumulate near growth tips, like shoots and flowers. For this reason, most deficiency symptoms occur in the newly formed tissues of the plant. In hemp, calcium deficiency may show up as brown or bronze spots on new leaves.

Micronutrients

The need for micronutrients for hemp is highly dependent on soil nutrient conditions, organic matter content, and soil texture. Copper (Cu) deficiency is commonly experienced in peat soils and its deficiency in hemp could lead to breaking of stems. Manganese (Mn) and boron (B) deficiencies have also been reported in hemp. One study conducted on peat-humus soils showed the yield and quality of fiber and seed hemp fertilized with sufficient P and K could be increased by supplemental application of 0.9 lb. of B (as boric acid (H3BO3)), 0.9 lb. of Cu (as copper sulfate (CuSO4)), and 8.92 lb. of Mn (as manganese sulfate (MnSO4)) per acre. Leaf tissue analysis of CBD hemp during deficiency symptomology for a wide range of nutrients including Mg, Sulfur (S), B, Cu, Mn, molybdenum (Mo), and zinc (Zn) were reported. This study also suggested that with the exception of N, K, B, and Cu, other nutrient deficiencies did not significantly decrease the CBD hemp yield. More research at field scale is necessary to evaluate the effect of micronutrients on the cannabinoids in CBD and seed yielding hemp varieties.

Fertility Summary:

We have not yet determined optimum fertility rates for hemp grown in NJ. The best information we have currently is from Pennsylvania. Penn State has developed fertilizer recommendations for hemp grown for seed harvest. In a soil with optimum levels of phosphorus (P) and potassium (K), recommendations for a crop with a 1,500-pound yield potential would be 150 pounds of nitrogen (N), 30 pounds of phosphate (P_2O_5), and 20 pounds of potash (K_2O). Fertility recommendations are slightly different for hemp grown for fiber compared to seed. At optimum P and K soil test levels a recommendation would be 150 pounds of N, 20 pounds of P_2O_5, and 20 pounds of K_2O. Industrial Hemp Production (psu.edu)

HEMP PRODUCTION SYSTEMS

If considering hemp production, keep in mind that there have been very few U.S.-based agronomic research studies on hemp since the early 20th century. Information from previous research is important and useful but may not always be completely applicable for modern production systems. Hemp has been grown as a crop in New Jersey on a limited basis since 2020. Research is needed to provide data on planting, management, fertility, harvesting, and processing specific to New Jersey. As a result, production information gaps may be encountered in the short term.

Hemp cultivation requires significant management, as well as specific field and environmental conditions specific to the type of hemp product being harvested. Hemp production is impacted by seedbed preparation, soil type, day length, seeding rates, seeding dates, row spacing, harvest dates, and soil moisture among other variables. Hemp varieties grown for fiber, oil seed, and CBD have different cultural requirements.

It cannot be emphasized enough that there are differences in production systems based on the end use of the hemp. It is difficult and may not be possible to pivot and change end use once the crop is established. For this reason, it is important to know the market you are producing hemp for and understand the production system that will allow you to economically produce hemp for that market. This guide provides information for producers investigating growing and marketing hemp. Hemp grown for grain or fiber production more closely matches existing grain and forage cropping systems than that of hemp grown for CBD. Field grown hemp for CBD production is more aligned with specialty crop floral production.

Different plant parts are harvested from hemp for specific purposes. Depending on the harvestable plant part of interest, (i.e., fiber, grain, or cannabinoids) male plants and pollen might be required for production, or completely unnecessary, or even excluded from production through management. There are 3 primary markets for hemp products – grain, fiber, and CBD. Each market is unique and requires hemp to be produced differently.

Hemp End Uses

The grain (seed) of hemp can be used in numerous ways. As a dietary supplement it is very rich in omega-3 and omega-6 fatty acids compared to other potential sources. It is relatively high in oil content. Hemp grain processors produce a wide array of products including toasted hemp seed, hemp seed oil, hemp flour, and even hemp coffee. It is used as bird feed and livestock feed, much the same as soybean hulls are used today.

Uses of hemp fiber have evolved greatly since the late 19th and early 20th centuries where it was used primarily for rope and cloth. Today hemp fiber can be used in many products ranging from construction materials, concrete additives, and many other materials.

Cannabidiol (CBD) oil is extracted from resins produced largely in female flowers. CBD is used as a health supplement with purported health benefits including pain relief, inflammation, and others (*Rutgers and the authors of this guide do not support or deny health claims for hemp products).* Much of the anticipated growth in the hemp industry is expected to be related to production of CBD and related value-added products.

Soil Suitability for Hemp Production

Hemp will grow on a wide variety of soil types and conditions. Hemp tends to grow best on deep soils with good fertility and drainage with a pH from 6.0 to 7.0. Hemp can do well on sandy light textured soils due to its large tap root that can source moisture and nutrients from deeper in the soil profile.

Hemp does not grow well in wet soils. Wet soils can restrict root and shoot growth, reduce fiber quality, and result in uneven plant heights that present challenges at harvest. Heavy clay soils present the biggest challenge to growing hemp. In the early stages of hemp growth, young plants do not withstand cool, waterlogged soils. Soil compaction, which is more prevalent on heavy clay soils, can cause an increase in seedling mortality. Clay soils with poor drainage can remain wet for long periods of time and impact hemp growth. Before irrigating, be sure soil

moisture levels indicate soil water is lacking and monitor to be sure fields are not being overirrigated. Tools like tensiometers (pictured to the right) can be used to monitor soil moisture.

Too much irrigation can promote root and crown diseases and leach fertilizer in the soil.
Test your soil several months (at least 6 months) before planting and apply lime and fertilizers as needed to obtain optimal optimum yields.

Tensiometer in the field displaying moisture levels in the root zone. Photo by, Michelle Infante-Casella

Soil preparation for hemp is similar to other spring crops. Hemp seeds require a firm seedbed and good soil contact to germinate well. Hemp could likely be grown in no-till and reduced-till systems, but this approach is not well-studied. A lack of currently registered herbicides also adds to the uncertainty of using reduced-till systems. Soil temperature, growing season length, and frost danger dictate when to plant hemp.

Plant Spacing Considerations

Plant spacing in hemp is dependent on the type of crop cultivated, i.e., fiber, seed, or CBD. Hemp cultivated for fiber is typically planted close together to promote stalk elongation while reducing branching; attributes that will ensure longer and stronger fiber yield. Target plant population for hemp seeded for fiber production can be as high as 35 plants per square foot (+1.5 million plants per acre). This high plant density promotes tall growth and can help suppress weeds, thereby reducing the need for herbicides. Hemp planted for seed can be as high as 15 plants per square foot (+650,000 plants per acre), while plants grown for CBD are well spaced out to maximize the desired flowering and branching. It is important to note that hemp seed size and germination rate can vary significantly between varieties. Producers should adjust seeding rates accordingly. See type of hemp for end use in sections below for more information on spacing.

Proper Variety Selection

Variety selection will be key to successful production of all hemp types for many reasons; one of the most important varietal traits is days to maturity (latitudinal adaptation). For grain growers, this is similar to how soybean varieties are selected according to maturity group. There are several considerations when selecting the correct variety for production. For example, varieties bred primarily for grain production could have significantly different

maturity dates relative to each other, and therefore would have very different establishment dates for maximum yields and a crop that is harvestable with standard equipment. Producers growing hemp for CBD production or for dual-use production systems will likely require different varieties to maximize yields and other characteristics.

As we begin to have more experience with hemp production, we are learning that varieties are regionally specific. Farmers looking to enter the hemp market for the first time will need to understand varietal options that are available and carefully determine which hemp variety is most suitable to their production and marketing strategies.

Quality seed is an essential part of any production system. Yields, disease and pest resistance, drought resistance, and stand uniformity are traits targeted in crop seed development. Hemp will undergo considerable breeding and cultivar development during the coming decade as the development of hemp seed genetics accelerates. Adding a new crop to crop rotations will require production related problems to be solved and development of crop genetics will play a key role in this effort. Using the proper seeding rates based on Pure Live Seed (PLS) is critical for successful hemp establishment and harvest. Recommended seeding rates are typically expressed as pounds of PLS/Acre.

Types of Hemp Production

For both grain and fiber crops, conventional field crop production practices are followed. There is the potential to utilize a no-till production system. Hemp production for CBD focuses on growing plants intensively as a specialty crop where flowers are cultivated for maximum growth. It should also be noted that there are limited herbicide, insecticide, or fungicide that are currently labeled for use in hemp crops. For continued updates on pesticides labeled for hemp see Pesticide Products Registered for Use on Hemp | US EPA. Lack of pest management options are a major production risk for producers to consider before deciding to plant hemp.

1. Hemp for Grain

Grain varieties are selected for food and nutritional applications. Grain varieties have high protein, fatty acid, and seed fiber content and usually have lower CBD content. Hemp production for fiber and/or grain can be highly mechanized with labor demands per acre similar to that of other agronomic crops. Hemp can be planted with a grain drill such as used for wheat. The seed is fragile and can be damaged during planting. Grain production may be optimized with no more than 150,000 plants per acre and sowing 20 to 30 lb/A of seed. Grain varieties are often shorter in height, reducing the amount of biomass that passes through the

combine and reducing wrapping in the combine. Grain hemp seed is thin-walled and can be fragile. The fragile seeds must be handled with care when harvested and transported to market. Move grain at low auger speeds to reduce grain damage.

Harvesting hemp grain by combine is the norm and some have suggested settings similar to those used for grain sorghum. Proper harvesting, processing, transportation, and storage are critical to prevent spoilage and ensure the highest value. Grain should be harvested when shattering begins. The rest of the plant will still be green and about 70% of the seed will be mature. Hemp is ideally combined at a moisture content of 10 to 20% moisture. Variety selection is key as the growth habits of those varieties bred primarily for grain production are more conducive to combine harvest. The combine header should be kept high enough to get the grain while minimizing stem that needs to pass through the combine. Grain from varieties bred primarily for fiber production could be difficult to harvest efficiently by combine.

2. Hemp Fiber Production

Fiber varieties of hemp produce long fibers and increased biomass. Fiber hemp varieties are generally taller and favor vegetative growth over seed production. These types of hemp have a wide range of uses, including textiles, building materials, pulp/paper, and more. Ideally, producers of hemp fiber will have access to processing facilities nearby due to the bulk of the product and cost of transport.

When growing hemp for fiber only production, seeding rate is often double what is used for grain production. Recommended seeding rates range from 40 to 60 lbs/A. Significant research is limited regarding seeding rates to achieve high yielding and good quality fiber. Planting too low a plant population will not provide competition for early season weed control. Hemp for fiber is planted in dense stands to promote taller height and discourage branching and flowering, thus maximizing fiber yields. Higher seeding rates encourage a higher quality fiber crop. Good quality hemp fiber comes from tall and thin plants. Higher seeding rates result in high plant population with tall thin plants with longer internodes.

Harvesting fiber crops is more complex than harvesting grain. Fiber crops will require retting prior to baling. Conventional hemp fiber production relies on field drying and straw retting – a process by which microbes degrade the pectin layer between the plant's bast fibers and woody core. Sufficient moisture assures the microbial degradation processes occur, but dry weather also is required to ensure the hemp stalks can be baled, weather conditions can affect fiber quality. Field retting hemp requires skills similar to producing high-quality hay. Successful field

retting will be dependent on weather conditions just as making good hay. Harvesting hemp stems for fiber with standard hay equipment can be difficult. Current common practice involves mowing by sickle-bar or mower-conditioner without conditioning/macerating, retting in the field, followed by baling. Hemp is swath or windrow cut for fiber production at about 8" from the soil surface, between early bloom and seed set when the lower leaves of female plants begin to yellow.

3.Dual Use (Hybrid) - Fiber and Grain Production

Dual Use varieties of hemp produce both fiber and seed, but do not have the yields or quality of single purpose cultivars. It is not uncommon for producers to harvest hemp grain with conventional grain combines and subsequently harvest the remaining stems for fiber. This is the most common example of a dual-purpose industrial hemp crop.

4. Cannabinoid (CBD) Production

This production system is sometimes referred to as floral or bud production. To grow hemp for CBD production, the crop is generally grown intensively as a specialty crop and the flowers are cultivated for maximum growth. CBD varieties are currently the most profitable for agricultural production and marketing. CBD varieties can present regulatory challenges when attempting to obtain the highest yield of CBD, while keeping the THC within allowable levels. High CBD varieties are generally grown utilizing only female plants, as the combination of male and female plants leads to increased seed production and decreased cannabinoid yields. Hemp varieties grown for CBD are different from the seed or fiber producing varieties.

Plants are usually dioecious, having separate male and female plants. Plants can also have the tendency for hermaphroditism (the inclusion of both male and female flowers on a single plant) based on plant genetics and environmental conditions such as water or heat stress. When selecting planting stock for CBD production it is important to consider the pros and cons associated with non-feminized seed, feminized seed, and vegetative clonal cuttings. Planting from seed, offers two options: non-feminized seed and feminized seed. Non-feminized seed will generally be less expensive and result in a roughly 50/50 split of males and females. Feminized seed will be more expensive but should result in greater than 90% female plants. Vegetative clones are the most expensive option. Clones provide consistency and stability of traits within a variety.

Because seeds for CBD hemp are expensive, they are rarely direct seeded. Instead, they are germinated in greenhouse flats and transplanted in the field two to four weeks after

emergence. Soil is often cultivated into irrigated, raised beds that are 2–4 feet wide, on 5- or 6-foot centers, and then covered with plastic mulch, similar to some vegetable crops. Soil beds enhance soil warming, improve weed control and moisture retention. Plants produced for optimal bud production are often spaced on a 4-6’ center for each plant within rows. Row spacing between row centers should be at least 5-6 feet apart. While number of plants per acre is dependent on plant spacing and row spacing, generally 800-1800 plants per acre will be planted. See table below for plant populations for hemp grown for CBD based on field spacing.

Spacing (ft.)	Number of Plants/Acre
5 X 4	2,178
5 X 5	1,742
5 X 6	1,452
6 X 4	1,815
6 X 5	1,452
6 X 6	1,210

Hemp plants being prepared for transplanting
Photo by Stephen Komar

Regardless of spacing, be sure to provide enough space for tractors or harvesting equipment between rows and at the end of rows for ease of maintenance or harvest throughout the

season. Harvest begins after flowers have fully developed, this generally occurs between the end of September and mid-October. Harvest may also occur earlier based on THC levels as the crop begins to mature. It is not uncommon to begin crop harvest early to avoid the possibility of an entire crop loss due to regulatory THC exceedance.

Transplants should be planted after risk for frost consistent with USDA plant hardiness zones. Ideal planting time in NJ is from the end of May through the end of June. Seed can germinate at 50^{o} F but should be planted after danger of frost when using direct seeding methods. Plants will begin rapid root and shoot growth with adequate fertility. After 4-6 weeks, formation of "pre-flowers" will be evident, which will aid in determination of the sex of plants. Female plants produce a cluster of white hairs (stigmas) at nodes, conversely male plants will produce a small male flower cluster. These males should be removed and destroyed to prevent pollination of female plants later in the season.

The time of harvest will depend on the variety, planting date, and growing region. Russeting (browning) of stigmas (white hairs) on buds will be one of the first indicators of bud maturation. After the change in stigmas is noted, attention should be focused on trichomes, which can be observed with a 60x hand lens. magnification. Trichomes will cover bud and leaf surfaces and appear as tiny stalks with bulbous heads. Throughout the maturation process, trichomes will range from clear to amber. Clear trichomes will be underdeveloped lacking full resin development, whereas amber trichomes will often be fully developed but on the verge of degradation. At harvest, plants can be dried before trimming or processed immediately once harvested from the field. It can be easier to trim buds and remove leaves on freshly harvested plants.

Male hemp plant, undesired in CBD hemp production, Photo by William Bamka

Clear trichomes on hemp plant, Photo by William Bamka

Bucket lid debudder for bud removal from stem, Photo by William Bamka

Immature bud and trichomes on a CBD hemp plant. Photo by Stephen Komar

PESTS AND PEST CONTROL IN HEMP PRODUCTION

Diseases, Insects and Mites, and Weeds

A limited number of pesticides are currently registered for use in hemp production. Since December 2019, US EPA has approved adding hemp to the labeled use sites some pesticide products including fungicides, insecticides, and herbicides. Most all of the products are biopesticides and one is a conventional pesticide. See the EPA website for the most up-to-date information on approved pesticides for use on hemp. Not all products approved by the EPA are labeled for use in New Jersey. Conducting an 'Advanced Search' on CDMS.net is a good way to identify products approved for use on hemp in New Jersey. It is important to note that, while these products are *available*, the University has not conducted product efficacy trials on hemp grown in New Jersey. Certified organic hemp producers should always confirm these pesticides are allowable by their certifying agency prior to application. Mention of any pesticide, product, or company is not an endorsement by Rutgers University or the authors of this publication. As with any crop, pest, or pesticide application the first step is to correctly identify the pest and then decide on a management for the pest.

Pesticide Use Disclaimer: THE LABEL IS THE LAW

1) Before using a pesticide, check the label for up-to-date rates and restrictions. Labels can be downloaded from: http://www.cdms.net/, https://www.greenbook.net/ or http://www.agrian.com/labelcenter/results.cfm.
2) Pesticides listed may have other formulations or brands with the same active ingredient(s). ALWAYS CHECK THE LABEL:
    a) to ensure a pesticide is labeled for the same use,
    b) to ensure the pesticide is labeled for the desired crop, and
    c) for additional restrictions.
3) Check the label for the maximum amount of pesticide per application and the maximum number of applications per year.
4) Check the label for use of personal protective equipment, mixing instructions, application instructions, any area restrictions, and environmental concerns.

DISEASES OF HEMP

Hemp is susceptible to several diseases that can result in significant losses in yield, quality and the profitability of hemp grown in New Jersey. Many of the common diseases that impact other crops in New Jersey, have been reported to impact hemp. The weather in New Jersey during the typical growing season is often conducive to disease development throughout the crop's lifecycle. Since there currently are limited fungicides labeled for use in hemp, preventative methods are important to reduce economic losses caused by diseases.

Leaf Spots

Leaf spots caused by fungal pathogens *Septoria* sp. and *Bipolaris* sp. was commonly observed in our 2020 hemp trials. Fungal leaf spots are widely reported in New York, Kentucky, and several other states where high disease impact has been observed. Even at sites where hemp had not previously been grown, leaf spot diseases were reported in NJ, so weeds are considered an alternate host. Leaf spot inoculum can also persist in the soil and on crop residue. Infection is favored by hot, humid weather following rain which can also spread inoculum through wind and soil splash. There are several other fungal genera that cause leaf spots on hemp.

Septoria leaf spot, Photos by Stephen Komar

Bipolaris leaf spot
Photo sourced from: https://hemp.cals.cornell.edu/resource/diseases-affecting-hemp-new-york-2019/

Powdery Mildew

Powdery mildew is a common foliar disease under high humidity conditions. In the 2020 hemp trials in NJ, *Golovinomyces* sp. was isolated from hemp transplants with powdery mildew and determined to be the causal agent locally. Many other states also report powdery mildew infections on hemp. Nearby hemp or cucurbit fields, as well as infected crop residue, may serve as inoculum sources. Greenhouse production favors powdery mildew infection due to higher humidity, reduced airflow, and moderate temperatures compared to field production.

Powdery mildew. Photo by, Michelle Infante-Casella

Fusarium Wilt and Fusarium Crown Rot

Several species of *Fusarium* infect hemp plants causing **Fusarium wilt and Fusarium crown rot**. *Fusarium* spp. result in systemic, vascular infections by infecting hemp roots, crowns and stems. These fungal pathogens persist on crop residue and in soil and spread through the movement of soil or airborne spores.

Fusarium Wilt on hemp
Photo sourced from: https://hemp.cals.cornell.edu/resource/diseases-affecting-hemp-new-york-2019/

Sclerotinia White Mold

Sclerotinia white mold affects hemp stems and is best managed by crop rotation. However, white mold presents a management challenge because several crops and weeds are alternate hosts. Prevention requires good weed control, especially of broadleaf weeds, and a robust crop rotation schedule that avoids host crops such as soybeans, forage legumes, and many vegetable crops. *Sclerotinia sclerotium* is the causal agent of white mold and produces survival structures that can survive in the soil for 2+ years.

Sclerotinia White Mold
Photos sourced from: https://hemp.cals.cornell.edu/resource/diseases-affecting-hemp-new-york-2019/

Botrytis Gray Mold

Botrytis gray mold is caused by *Botrytis cinerea.* Gray mold is favored by high humidity, poor airflow, and moderate temperatures. Infection is most common in flower buds but can be observed on all plant parts. Infection enters through a wound or opening in plant tissue. Reducing injury to plants and maximizing airflow in the plant canopy may reduce incidence of disease.

Botrytis gray mold, Photo by Stephen Komar

Damping-Off

Damping-off is a phenomenon that occurs in seedlings, clones, and young transplants and is caused by *Pythium* spp. and *Rhizoctonia solani*. Damping-off is favored by wet soil conditions and high soluble salt content. Plants under stress are also more susceptible to infection. Infected plants will often exhibit characteristic wilting and often a lesion or girdling at the soil line. Good greenhouse sanitation is essential along with use of well-drained, disease-free planting medium. Use clean water and do not reuse planting medium to avoid introducing these pathogens. Discard infected plants and quarantine nearby plants.

Damping-off in the greenhouse. Photo sourced from https://extension.tennessee.edu/publications/Documents/W916.pdf

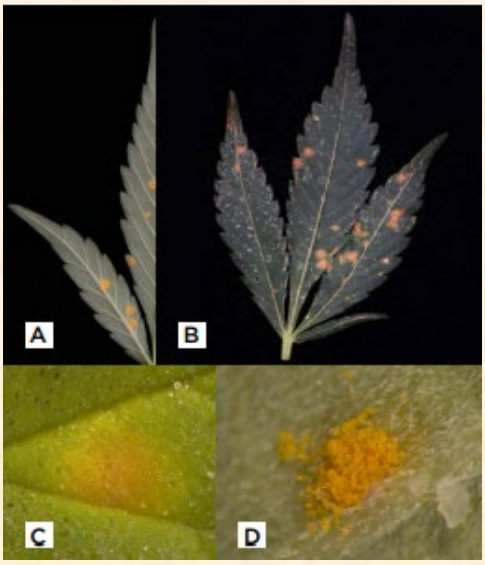
Southern Blight

Southern blight is caused by *Athelia rolfsii* (also known as *Sclerotium rolfsii*) infects the crown and stem of hemp plants. Southern blight infection is more common on sandy or sandy loam soils and occurs during hot, humid weather when there is high soil moisture. Random plants will often exhibit a sudden wilting and may exhibit yellowing. One characteristic sign of the disease is the presence of white fungal growth at the soil line and tan round balls called sclerotia that can persist for several years. Southern blight is a common disease in many agricultural crops including many vegetable crops. Since the sclerotia can survive for several years without a host, rotation to a grass crop is often the best management strategy.

A) Plant in the field displaying wilt and leaf yellowing resulting from southern blight infection B) White fungal growth and tan/brown sclerotia are observed near the soil line on a hemp plant infected with southern blight. C) A close-up view of the hardy overwintering sclerotia, which resemble mustard seeds. Photo sourced from https://extension.tennessee.edu/publications/Documents/W916.pdf

Hemp Rust

Hemp rust is a foliar disease of hemp caused by *Urdeo kriegeriana*. Spore dispersal from nearby hemp fields is the main source of inoculum. Initial rust symptoms occur as orange spots followed by orange spores (uredospores) often on the underside of leaves.



A) The underside of a hemp leaf showing orange rust spore pustules. B) Hemp rust lesions on the upper leaf surface. C) Lesions start as yellow/orange spots on the upper leaf surface. D) Orange spore clusters (pustules) containing spores (uredospores). Photo sourced from https://extension.tennessee.edu/publications/Documents/W916.pdf

Fusarium Bud Blight

Fusarium bud blight occurs in female flower buds and grains and infection may result in contamination by Fusarium mycotoxins. There is much concern over this potential for contamination and work is ongoing to understand differences in varietal susceptibility.

Fusarium bud blight, Photo by William Bamka

Disease Management

Although some of these diseases can result in substantial loss of plants and reduce the quality of the end products, economic thresholds for management of these diseases are not well understood and may vary across cropping systems. Preventative management is essential as there are currently only 19 fungicides approved for use on hemp in New Jersey (Table 1) – all of which are biopesticides. While pesticides are an important tool for disease management, they are just one of many tools available. An integrated approach to disease management in commercial hemp production is key, with modification of cultural practices and cultivar selection being the primary methods to mitigate disease incidence. Season-long best management practices include:

1) Pre-plant
    a) Purchase only disease-free plant material
    b) Avoid susceptible varieties
    c) Use well-drained planting medium
    d) Quarantine newly arrived plant material for 2-3 weeks
    e) Sanitize greenhouse between crops/seasons
    f) Never reuse planting medium for transplants
2) During growing season
    a) Maximize air flow in the plant canopy (row spacing and row orientation)
    b) Avoid overhead irrigation
    c) Allow soil to dry between watering events, avoid overwatering
    d) Prevent excessive, rapid plant growth (monitor fertility, especially N)
    e) Avoid physical or insect injury to the plant
    f) Control weeds, especially those that serve as alternate hosts
    g) Immediately remove infested plants and those nearby
    h) Remove soil around infested plants
    i) Burn, bury, or remove infested plant material (if burning obtain burning permit)
    j) Sanitize equipment and tools between use
3) Post-harvest
    a) Burn, bury, or remove infested plant material (if burning obtain burning permit)
    b) Control weeds, especially those that serve as alternate hosts
    c) Sanitize equipment and tools
    d) Employ a robust, 3–4-year crop rotation cycle

Table 1. Fungicides labeled for use in hemp production in New Jersey (current as of 15 October 2021, source: CDMS.net).

Product	EPA #	Manufacturer	Active Ingredient(s)
Brandt® Organics Aleo™	EXEMPT	Brandt Consolidated	Garlic Oil
Contans® WG	264-1174	Bayer CropScience	*Coniothyrium minitans* strain CON/M/91-08
Double Nickel® LC	70051-107	Certis USA, L.L.C.	*Bacillus amyloliquefaciens* strain D747
InLine® Soil Fungicide and Nematicide	62719-348	Corteva Agriscience United States	1,3-dichloropropene, Chloropicrin
MilStop® SP	68539-13	BioWorks, Inc.	Potassium bicarbonate
OxiDate® 2.0	70299-12	BioSafe Systems, LLC	Hydrogen Peroxide, Peroxyacetic Acid
OxiDate® 5.0	70299-28	BioSafe Systems, LLC	Hydrogen Peroxide, Peroxyacetic Acid
SaniDate® 12.0	70299-18	BioSafe Systems, LLC	Hydrogen Peroxide, Peroxyacetic Acid
SaniDate® 5.0	70299-19	BioSafe Systems, LLC	Hydrogen Peroxide, Peroxyacetic Acid
SaniDate® WTO	70299-19	BioSafe Systems, LLC	Hydrogen Peroxide, Peroxyacetic Acid
Sil-Matrix™	82100-1	Certis USA, L.L.C.	Potassium silicate
SporeQuell™ 15%	63838-2-90930	Miller Chemical & Fertilizer, LLC	Hydrogen Peroxide, Peroxyacetic Acid
StorOx® 2.0	70299-7	BioSafe Systems, LLC	Hydrogen Peroxide, Peroxyacetic Acid
TELONE® II Soil Fumigant	95290-1	Teleos Ag Solutions	1,3-dichloropropene
TerraClean® 5.0	70299-13	BioSafe Systems, LLC	Hydrogen dioxide, Peroxyacetic Acid
Thyme Guard®	EXEMPT	Agro Research International LLC	Thyme Oil
Thymox Control®	EXEMPT	Laboratoire M2	Thyme Oil
Veg'lys	EXEMPT	Phytoauxilium	Garlic Oil
ZeroTol® 2.0	70299-12	BioSafe Systems, LLC	Hydrogen Peroxide, Peroxyacetic Acid

Resources:

http://www.kyhempdisease.com/sanitation-for-disease-management-in-field-hemp.html
http://www.kyhempdisease.com/cultural-calendar-1.html
http://plantpathology.ca.uky.edu/files/ppfs-gen-16.pdf
https://www.lsuagcenter.com/profiles/bneely/articles/page1598388366494
https://hemp.cals.cornell.edu/resource/diseases-affecting-hemp-new-york-2020/
http://www.kyhempdisease.com/disease101---hemp-disease-management-basics.html
http://www.kyhempdisease.com/septoria-leaf-spot.html
http://www.kyhempdisease.com/gray-mold--botrytis--in--the-greenhouse.html
http://www.kyhempdisease.com/powdery-mildew-of-hemp.html
http://www.kyhempdisease.com/pythium-root-rot.html
https://extension.tennessee.edu/publications/Documents/W916.pdf
https://plantpath.ifas.ufl.edu/extension/hemp-diseases/
https://plantpathology.ca.uky.edu/files/sr112.pdf

INSECT AND MITE PESTS OF HEMP

There are a wide variety of insect and mite pests of hemp that have been observed in NJ trials and by others studying hemp across the country. While all parts of the hemp plant are vulnerable, pests that damage the flower buds or grain (e.g., corn earworm) may have the greatest potential impact on profitability. Like hemp diseases, management thresholds for pests of hemp are not well understood and will vary by cropping system.

Table 2. List of pests, plant parts affected, damage and management options for insect and mite pests of hemp.

PEST	PLANT PART AFFECTED	DAMAGE CHARACTERISTICS	MANAGEMENT OPTIONS
Cannabis aphid	Whole plant	Sooty mold growth Weakened plants Virus transmission	Purchase and plant only pest-free plants Scout before applying broad-spectrum insecticides to avoid disrupting populations of natural enemies
Corn earworm, tobacco budworm	Flower buds, grain, foliage	Feeds at base of developing buds, causing them to die Feed on foliage if no reproductive tissue available Feeding injury can create an opening for secondary pathogens that damage buds, grain	Start scouting when flowering begins Target pesticide application to small larvae Stay tuned to Veg IPM updates on Plant and Pest Advisory (blacklight and pheromone trap network throughout the state exists to monitor corn earworm populations and flight timing) Control weeds to limit food availability
Armyworms	Foliage	Feed on hemp foliage	Scout regularly Target pesticide application to small larvae
European corn borer	Foliage, stalk, large stems	Larvae feed on foliage then bore into stems	Monitor adult flights to time insecticide applications before larvae bore into stalk Chop, shred, or bury stalks after harvest to minimize overwintering sites
Eurasian hemp borer	Stalk, stems, buds	Larvae bore into base of developing buds, causing bud to die Stunting or distortion of stems Damage to developing seeds	Monitor adult flights to time insecticide applications before larvae bore into stems Monitor along field edges, where most infestations begin Smartweeds and hops are alternate hosts (control along field edges) Remove, shred, or bury crop debris after harvest
Flea beetles	Foliage, flowers	Feeding causes small holes in foliage; severe feeding leads to defoliation Greatest concern is with young plants	Crop rotation essential in fields with a history of infestations
Japanese beetle	Foliage, flowers	Adults skeletonize foliage	Available insecticides not sufficient to control
Potato leafhopper	Foliage	Stunting Staining of leaves	Use sweep net to monitor populations Use insecticides to target nymphal stages where populations are high

		Brown leaf edges followed by necrosis -"Hopperburn"	
Tarnished plant bug	Flowers, developing seeds, stems	Stunting Distorted leaves Aborted flowers Deformed seeds	Avoid growing hemp near alfalfa
Common stalk borer, burdock borer	Stalk	Boring of stalk causes plant to collapse	Control grassy weeds along field edges Rotate where damage has occurred Apply insecticides before larvae bore into stem where they are no longer susceptible
Two-spotted spider mite	Foliage	Plant cells appear silver, stippled, sandpaper-like Browning of leaves followed by leaf drop	Monitor: particularly on field edges and during periods of drought Soils where plants are more susceptible to drought stress may have greater pressure Apply miticides before infestations become excessive, ensure thorough coverage
Hemp russet mite	Foliage	Upward curling of leaves Leaves become off-colored, brittle Flower size decreases	

INSECTICIDES AND MITICIDES FOR MANAGEMENT IN HEMP

There are several products currently registered for insect and mite control on hemp grown in New Jersey (Tables 3, 4 & 5). While these products are approved for use by the US EPA, it is important to note that product efficacy research has not yet been conducted in New Jersey. Hemp is being added as a labeled use site to additional pesticides on a regular basis so these tables may not represent all labeled products at the time of reading this publication. See updates to approved pesticides on the US EPA website: [Pesticide Products Registered for Use on Hemp | US EPA]

Table 3. Insecticides labeled for use in hemp production in New Jersey (current as of 15 October 2021, source: CDMS.net).

PRODUCT	EPA #	MANUFACTURER	ACTIVE INGREDIENT
AGREE® WG BIOLOGICAL INSECTICIDE	70051-47	Certis USA, L.L.C.	*Bacillus thuringiensis* subspecies *aizawai* strain GC91
AGRO PEST™	EXEMPT	Agro Research Int. LLC	Rosemary Oil, Thyme Oil
ANCORA® MICROBIAL INSECTICIDE	70051-19-59807	OHP, Inc.	*Isaria fumosorosea* Apopka Strain 97
AZA-DIRECT®	71908-1-10163	Gowan Company	Azadirachtin
AZAGUARD® BOTANICAL INSECTICIDE/NEMATICIDE	70299-17	BioSafe Systems, LLC	Azadirachtin
AZATROL® EC INSECTICIDE	2217-836	PBI-Gordon Professional	Azadirachtin
BIOCERES® WP	89600-2	Anatis Bioprotection Inc.	*Beauveria bassiana* Strain ANT-03
BOTANIGARD® ES	82074-1	BioWorks, Inc.	*Beauveria bassiana* Strain GHA
BRANDT® ECOTEC® PLUS	EXEMPT	Brandt Consolidated	Geraniol, Peppermint Oil, Rosemary Oil
CAPTIVA®	10163-326	Gowan Company	*Capsicum oleoresin* extract, Garlic Oil, Soybean Oil
CAPTIVA® PRIME	10163-336	Gowan Company	Canola Oil, *Capsicum oleoresin extract,* Garlic Oil
CEDAR GARD™	EXEMPT	Natural Resources Group, Inc.	Cedar Oil
CELITE® 610	73729-1	Imerys Filtration Minerals Inc.	Diatomaceous Earth
DEADZONE™	73729-1	Imerys Filtration Minerals Inc.	Diatomaceous Earth
ECOZIN® PLUS 1.2% ME	5481-559	Amvac Chemical Corp.	Azadirachtin
GF-120® NF NATURALYTE® FRUIT FLY BAIT	62719-498	Corteva Agriscience United States	Spinosad
HELICOVEX®	69553-2	Andermatt Biocontrol AG	*Helicoverpa armigera nucleopolyhedrovirus* strain BV-0003
INLINE® SOIL FUNGICIDE AND NEMATICIDE	62719-348	Corteva Agriscience United States	1,3-dichloropropene, Chloropicrin
JAVELIN® WG BIOLOGICAL INSECTICIDE	70051-66	Certis USA, L.L.C.	*Bacillus thuringiensis* subspecies *kurstaki*
LEPROTEC®	89046-12-88847	Vestaron Corporation	*Bacillus thuringiensis* subspecies *kurstaki* strain EVB-113-19
MOLT-X®	68539-11	BioWorks, Inc.	Azadirachtin
MYCOTROL® ESO	82074-1	BioWorks, Inc.	*Beauveria bassiana* Strain GHA
PFR-97® 20% WDG	70051-19	Certis USA, L.L.C.	*Isaria fumosorosea* Apopka Strain 97
PYGANIC® SPECIALTY	1021-1772	MGK Company	Pyrethrins
SIL-MATRIX™	82100-1	Certis USA, L.L.C.	Potassium silicate
SPEAR®-LEP	88847-6	Vestaron Corporation	GS-omega/kappa-Hxtx-Hv1a
SPEAR®-T LIQUID CONCENTRATE	88847-6	Vestaron Corporation	GS-omega/kappa-Hxtx-Hv1a
TETRACURB™ CONCENTRATE	EXEMPT	Kemin Industries, Inc.	Rosemary Oil
THYME GUARD®	EXEMPT	Agro Research International LLC	Thyme Oil

Table 4. Miticides labeled for use in hemp production in New Jersey (current as of 18 October 2021, source: CDMS.net).

PRODUCT	EPA #	MANUFACTURER	ACTIVE INGREDIENT
AGRO PEST™	EXEMPT	Agro Research International LLC	Rosemary Oil, Thyme Oil
ANCORA® MICROBIAL INSECTICIDE	70051-19-59807	OHP, Inc.	*Isaria fumosorosea* Apopka Strain 97
AZA-DIRECT®	71908-1-10163	Gowan Company	Azadirachtin
AZAGUARD® BOTANICAL INSECTICIDE/NEMATICIDE	70299-17	BioSafe Systems, LLC	Azadirachtin
AZATROL® EC INSECTICIDE	2217-836	PBI-Gordon Professional	Azadirachtin
BRANDT® ECOTEC® PLUS	EXEMPT	Brandt Consolidated	Geraniol, Peppermint Oil, Rosemary Oil
CAPTIVA®	10163-326	Gowan Company	Capsicum oleoresin extract, Garlic Oil, Soybean Oil
CAPTIVA® PRIME	10163-336	Gowan Company	Canola Oil, Capsicum oleoresin extract, Garlic Oil
CELITE® 610	73729-1	Imerys Filtration Minerals Inc.	Diatomaceous Earth
PFR-97® 20% WDG	70051-19	Certis USA, L.L.C.	*Isaria fumosorosea* Apopka Strain 97
SIL-MATRIX™	82100-1	Certis USA, L.L.C.	Potassium silicate
SPEAR®-T LIQUID CONCENTRATE	88847-6	Vestaron Corporation	GS-omega/kappa-Hxtx-Hv1a
TETRACURB™ CONCENTRATE	EXEMPT	Kemin Industries, Inc.	Rosemary Oil

Table 5. Products labeled for control of major pests of hemp in New Jersey (current as of 15 October 2021, source: CDMS.net)

Product	Cannabis Aphid	Corn Earworm and Tobacco Budworm	Army-worms	Borers	Flea Beetles	Japanese Beetles	Potato Leaf-hopper	Tarnished Plant Bug	Hemp Russet Mite	Two-spotted Spider Mite
Agree® WG Biological Insecticide		x	x	x						
Agro Pest™	x								x	x
Ancora® Microbial Insecticide	x	x	x	x						x
Aza-Direct® **	x	x	x	x	x	x	x	x		
AzaGuard® Botanical Insecticide/Nematicide	x	x	x	x	x	x	x	x	x	x
Azatrol® EC Insecticide	x	x	x	x	x	x	x	x	x	x
BioCeres® WP	x			x				x		
BioLink® Insect & Bird Repellant	x	x	x	x	x	x	x	x	x	x
BotaniGard® ES			x	x	x			x		x
Brandt® Ecotec® Plus	x	x	x	x	x	x	x		x	x
Captiva®		x	x	x			x	x	x	x
Captiva® Prime		x	x	x			x	x	x	x
Cedar Gard™			x	x	x	x	x	x		
Celite® 610	x	x	x	x	x	x	x	x		
Deadzone™	x	x	x	x	x	x	x	x		
Ecozin® Plus 1.2% ME	x	x	x	x	x	x	x	x		
Helicovex®		x								
Javelin® WG Biological Insecticide		x	x	x						
Leprotec®		x	x	x						
Molt-X®	x	x	x	x	x	x	x	x		
Mycotrol® ESO			x	x	x		x	x		x
PFR-97® 20% WDG	x	x	x	x		x		x		x
PyGanic® Specialty	x	x	x		x	x	x	x	x	x
Sil-Matrix™	x								x	x
Spear®-Lep		x	x	x						
Spear®-T Liquid Concentrate	x									x
TetraCURB™ Concentrate	x									x

**Check the label for county-specific restrictions on application

Resources:

https://ipcm.wisc.edu/download/pubsPM/Hemp_Insects_final.pdf

https://webdoc.agsci.colostate.edu/hempinsects/PDFs/Rice%20root%20aphid%20with%20photos.pdf

https://webdoc.agsci.colostate.edu/hempinsects/PDFs/Eurasian%20hemp%20borer%20September%202018%20rewrite(1).pdf

https://webdoc.agsci.colostate.edu/hempinsects/PDFs/Zebra%20Caterpillar%20NEW.pdf

https://webdoc.agsci.colostate.edu/hempinsects/PDFs/Variegated%20cutworm%20October%2012%202017.pdf

https://webdoc.agsci.colostate.edu/hempinsects/PDFs/Yellowstriped%20Armyworm%20october%2012%202017.pdf

https://webdoc.agsci.colostate.edu/hempinsects/PDFs/Potato%20leafhopper%20Hopperburn.pdf

https://webdoc.agsci.colostate.edu/hempinsects/PDFs/Leafhoppers%20Revision%202020.pdf

Hemp Insect. 2021. *Hemp Insect Fact Sheets - Hemp Insect*. [online] Available at: https://hempinsects.agsci.colostate.edu/hemp-insects-text/ [Accessed 8 November 2020].

Berlingeri, J., Chartrand, M. and Shields, E., 2021. *Insect Pests, Pollinators, And Beneficials In New York State Industrial Hemp: An Overview – Cornell Hemp*. [online] Hemp.cals.cornell.edu. Available at: https://hemp.cals.cornell.edu/docs/insects-new-york-state-industrial-hemp/ [Accessed 8 November 2020].

Pulkoski, M. and Burrack, H., 2020. *Corn Earworm and Tobacco Budworm in Industrial Hemp | NC State Extension Publications*. [online] Content.ces.ncsu.edu. Available at: https://content.ces.ncsu.edu/corn-earworm-and-tobacco-budworm-in-industrial-hemp [Accessed 27 January 2021].

Gallery of Insects and Insect Damage on Hemp:

Tobacco Budworm and Corn Earworm Larvae
Photo by Aurora Toennission, NC State University *CC BY-NC - 4.0*

Tobacco budworm moth. Photo by Whitney Cranshaw, Colorado State University, Bugwood.org CC BY - 4.0

Corn earworm moth, Photo by Whitney Cranshaw, Colorado State University, Bugwood.org CC BY - 4.0

Frass (excrement) from corn earworm, Photo by Stephen Komar

Corn Earworm on Hemp Bud, Photo by Stephen Komar

Cannabis Aphid on Hemp. Photo by Stephen Komar

Yellow-Striped Armyworm
Photo sourced from: https://agsci.colostate.edu/hempinsects/hemp-insects-text/

Beet armyworm
Photo sourced from: https://agsci.colostate.edu/hempinsects/hemp-insects-text/

Eurasian Hemp Borer
Photo sourced from: https://agsci.colostate.edu/hempinsects/hemp-insects-text/

Stink bug on hemp leaf, Photo by Stephen Komar

Leafhoppers
Photo sourced from: https://agsci.colostate.edu/hempinsects/hemp-insects-text/

Two-Spotted Spider Mite
Photo sourced from: https://agsci.colostate.edu/hempinsects/hemp-insects-text/

Natural Enemies of Hemp Pests

Natural enemies play an important role in the management of agricultural pests. Given the lack of approved pesticides and pesticide efficacy data on hemp grown in New Jersey, hemp growers may wish to encourage natural enemy populations to aid in biocontrol of pest species. Examples of these beneficial insects include Big-eyed bug (*Gercoris* spp.), damsel bugs, Syrphid flies, Convergent Lady Beetle (*Hippodamia convergens* L.), Minute Pirate Bug (*Orius insidious*), Green Lacewings (*Chrysoperla rufilabris* L.), and Brown Lacewings (*Hemerobius* spp.). More information on these species can be found here. For information on best management practices to encourage these beneficial insects on your farm, visit Michigan State University's Native Plants and Ecosystem Services website and check out ATTRA's publication: "Farmscaping to Enhance Biological Control."

Big-Eyed Bug on a Stem, Photo by Whitney Crenshaw, Colorado State University, Bugwood.org

Lady Beetle, Photo by Michelle Infante-Casella

WEED CONTROL

When it comes to weed control in hemp, there are few rescue options and no labeled conventional herbicides as of October 2021. Prevention of weeds and mechanical removal of weeds are the current best management practices for weed control in hemp fields. Starting with a weed-free field, avoiding fields with problematic weeds, and not using fields with highly aggressive weeds should be considered. Mechanical options like disking or cultivating fields may intensify some weeds problems by cutting roots of underground spreading weeds, resulting in more weed development and spread of weeds throughout the field. In addition, cultivation can bring weed seeds closer to the soil surface, encouraging germination of weed seedlings. Using management practices, like mulches, to prevent weed problems are the best ways to discourage weed populations.

Field history and past herbicide applications

An important management tool is to know what herbicides were applied to the previous season's crop. Herbicides applied to previous crops can impact hemp establishment and development. Since hemp is a relatively new crop, it is not listed on many herbicide labels. Therefore, rotational restrictions fall under "other crops" when searching for this information on herbicide labels.

Design crop rotations to optimize weed suppression

Growing the same crop year after year will favor the same weeds, thus rotating crops will prevent weeds from becoming adapted to your field. Rotate between crops has different characteristics such as planting date, emergence, height, and nutrient requirements. Ultimately, crop rotation will allow you to protect poor competitor crops by planting them after competitive crops in which weed populations will be reduced.

Have the right cultivation tools

Determine what type of cultivation tools are available on the farm, or what is needed for weed control, and design a field plan based on the tools available. For example, if a cultivator is only 4 feet wide and the row spacing is 5 feet wide, the extra space may be difficult to manage. Asking the question of what row spacing will be used to optimize the efficiency of cultivation tools and accommodate optimal row spacing for the crop will help make these decisions.

Utilize cultural weed control practices

Prevent the arrival of new weed species by ensuring the use of weed free seeds or transplants and cleaning equipment prior to entering the field. Using both plastic mulch for in-row weed control and organic mulches, like straw, to prevent weeds between rows is recommended for hemp grown for CBD production.

Straw mulch between rows for weed control, Photos by William Bamka and Stephen Komar

Take notes on weed emergence annually to gauge timing of weed emergence

Knowing what weeds are in the field, their life cycle and when they emerge will help with planning the timing of mechanical weed control. For example, common lambsquarters are a summer annual and emerge in spring. In contrast, eastern black nightshade is another summer annual but emerges after common lambsquarters and common/giant ragweed.

US EPA Labeled Herbicides for Weed Control in Hemp

(current as of November 2021):

Capric acid and Caprylic acid

Trade Names: FireWorxx 80, Homeplate Total Vegetation Killer) EPA REG. NO. 67702-54

Product Information:

A fast-acting, non-selective broadleaf weed, grass, algae and moss killer. This product is not translocated. It will burn only those plant parts that are coated with spray solution. This product can be used any time during the year and works best during warm and dry conditions. Application during cold weather may delay the appearance of plant damage. If rain falls within 3 hours of treatment, an additional spray may be required. This product controls many common annual weeds and suppresses the growth of some biennial and perennial weeds. It can be used in cultivated areas prior to planting grass, flowers and vegetables. Areas can be replanted as soon as the desirable level of weed control is obtained. Do not spray on desirable plants. OMRI listed.

Uses: 1. Vegetation Burndown 2. Directed and Shielded Sprays 3. Pre-plant Application 4. Post-Harvest Spray (annual crops) 5. Sucker Control, Pruning and Trimming.

Label: US EPA, Pesticide Product Label, Fireworxx 80,06/15/2020

Acetic Acid

Trade Names: WeedWorks WEED & GRASS KILLER

EPA Registration No. 81936-1

Product Information:

Weed Works is a fast-acting, non-selective contact killer containing an acid that is non-residual in soil. Foliar contact results in rapid desiccation and control of annual weeds and grasses, and top growth reduction of herbaceous perennial weeds and grasses (see tables below). Retreatment may be required for control of established perennial weeds. Weed Works can be applied up to an including the day of harvest. Do not apply to desirable plants.

Label: US EPA, Pesticide Product Label, WEED WORKS WEED & GRASS KILLER,01/27/2020

Vinegar

Trade Names: Vinagreen, Vinweed, Vinish, Invincible, Vinvicide, Tervinate, Vinquish, Kilgar, Strongar

EPA Registration No. 85208-1

Product Information: Vinegar is a quick-acting, non-selective contact herbicide containing an organic acid for which the residues degrade promptly in soil. Foliar contact results in rapid desiccation and control of annual weeds and grasses, and top growth reduction of herbaceous perennial weeds and grasses. For control of established perennial weeds, retreatment may be necessary. Vinegar can be applied up to two days before harvest. Do not spray directly onto desirable plants. For best results, spray on dry leaves at temperatures between 50 and 75 degrees Fahrenheit. Weather conditions that favor high evaporation rates may result in reduced efficacy. Product is not to be diluted with water and can be used for spot treatments or broadcast for burn down of large areas. Do not allow to drift from the target site. See label for more information.

Label: US EPA, Pesticide Product Label, VINAGREEN,03/08/2019

HARVESTING HEMP

Harvest for Seed Production

For seed production, hemp is harvested when seeds begin to shatter. The plants will still be green. At this time about 70 percent of the seeds will be ripe, and the seed moisture is often about 22–30 percent. If harvesting is delayed, then grain losses can increase from shattering, bird damage, and lower grain quality. There is also a greater problem with the fiber in the stalks wrapping in the combine. Avoiding taller varieties can help reduce the amount of material going through the combine. Grain combines can be used for grain harvest and some recommendations have suggested settings like those used for grain sorghum. Hemp grain is thin-walled and fragile, requiring care in harvest, storage, and transport. Grain should be dried at once after harvest to less than 10% moisture.

Harvest for Fiber Production

Harvest for fiber production in many ways is like harvesting forages. Forage harvesting and handling equipment have been reported to perform well without major modifications. One common caution that can be found regarding fiber production is that any machinery with rotation, pickup heads, or rolling bearings can easily lead to hemp wrapping to the point where machinery can become plugged. Hemp cutting can be carried out with a disc bine, a disc mower, or a straight sickle mower. Specialized equipment for cutting hemp for fiber is available from some overseas manufacturers. There are reports that swathers and haybales do not work well, especially with very tall crops, as there is a tendency for long stems to wrap on the reel.

Once cut for fiber, hemp must undergo retting. Retting is a process involving the use of moisture and microbes to break down the bonds holding the hemp stem together, enabling easier separation of fibers. Field retting is most used where the hemp is left in the field to partially decompose naturally from dew, molds, and bacteria. This process can take 4–6 weeks depending on the weather and must be closely watched. After retting, the stalks are dried to a moisture content of less than 15% and baled. A baler may be used to bale the hemp stalks, at which point the stalks are ready for storage.

CBD Floral Harvest

There is no established technique for CBD harvest on a large-scale acreage. Research is needed to understand the best way to harvest CDB for large-acreage production. Currently most CBD production is on small-acre plots or in greenhouses. The first step in the CBD flower harvest is to harvest live plants. There are visual clues on the hemp bud that growers should monitor as harvest approaches. Many observe trichomes to gauge harvest readiness. When trichomes on the hemp bud shift from white to milky white it may be time to harvest. Keep in mind that THC testing is required to stay in compliance with regulations so simply relying on visual clues is not recommended for beginners. Harvest for CBD production can be very labor intensive.
Harvesting hemp at the proper stage is critical for CBD production. The presence of molds and mildews will lower the value of hemp floral biomass. Current reports show most hemp growers producing for the CBD market rely on manual labor to cut the stalks. This is carried out often with a machete or a lopper. Once plants are harvested, growers should at once move the floral biomass into the drying facility. Some producers choose to debud the plant prior to drying. Others dry the entire plant and then perform the debudding operation. Slow drying with high airflow will cure the hemp flowers and produce a higher quality product.

POST HARVEST HANDLING AND STORAGE OF HEMP

As with most other aspects of producing hemp, it cannot be emphasized enough that there are differences in the post-harvest handling and storage of hemp based on the end use of the crop. Hemp fiber generally requires the least effort, grain needs more handling, and drying hemp flower for cannabinoids can range from simple to complex, depending on the final market (CBD or smokable bud). Proper planning for handling and storing the crop prior to producing and harvesting your first hemp crop is vital. Skipping this step can result in significant economic losses. As in most agricultural processes, the ability to quickly and cost effectively dry the harvested material is a critical step in ensuring farmers can recognize profit from months of labor and inputs. Understanding of best practices for hemp biomass storage is an ongoing learning process in these early years of licensed cultivation. The ability to properly dry hemp is one of the most important steps in hemp processing and production operations. Even if high quality hemp is grown, failure to thoroughly dry the harvested plant material can turn a profitable harvest into a lost crop overnight. Proper storage ensures all the effort that went into drying hemp is not wasted. Just as the end use for each hemp crop determines best practices for drying, hemp grown for fiber, grain and flower require different storage methods. Post-harvest handling and storage for CBD floral, grain and fiber production is discussed below.

Floral Production

Postharvest, hemp contains up to 80% moisture, and drying helps preserve cannabinoids before extraction. Adequate space and drying capacity are major considerations when producing for the floral market. As the crop must be typically harvested all at once, there is a significant amount of plant biomass to be removed from the fields. There is a potential to handle large quantities of plant material in a short time frame. This is particularly of concern when trying to harvest quickly to avoid a THC spike - which could result in the crop being non-harvestable due to regulatory non-compliance. Most plants harvested directly from the field will take up 3-5 square feet unless bucked from the stalk. Potential handling space requirements can be estimated based on acreage planted and plant population.

Drying is the primary step of the post-harvest process. Drying flowers requires an optimal balance of humidity and temperature. This important phase reduces the moisture content of the hemp to 10-15% moisture. If the plan is to extract and distill CBD oil, then plants just need

to be dried. If the plan is to sell buds to smoke, then buds need to be cured. Plants for high-end markets such as smokable hemp shouldn't be exposed to high heat because they can lose the flavoring that makes them marketable. Once harvested, floral plant material should be directly transported to the drying facility. Hanging entire plants upside down on wires in the drying facility is a common practice. When plants are hung upside down there is potential for branches to drop down, causing less air flow into the interior of the plant - resulting in the potential for less efficient drying and mold formation in the inner branches. To combat this some producers, break off individual branches from the whole plant for drying. The drying facility could be a simple structure like a barn. Some producers use shipping containers with dehumidifiers as drying facilities. The drying facility should be under a roof, out of direct sunlight, and well ventilated. Significant ventilation is crucial and should target one air exchange per hour. At a minimum, a drying barn should include several fans blowing continuously. Slow drying with high airflow will cure hemp, which produces a higher quality end product. Ideal temperatures for drying and curing are 60 to 70 degrees F at 60% humidity. Buds may take 1-12 days to dry, depending on the initial moisture content, bud size, individual plant density and density of plants in the facility. Drying is done at a much slower rate when curing, usually taking 2-4 weeks to dry.

The prevention of mold while handling and storing product is of the utmost importance. Disregarding climate controls or allowing products with varying moisture content to sit alongside one another in storage will create conditions for mold growth. Day-to-day monitoring of humidity levels is critical. Low humidity must be maintained to prolong storage life. Long term storage of floral buds is favored by a constant 10% moisture content.

Grain Handling and Storage

Hemp seed must be properly dried, stored and monitored to preserve grain quality. Heated or moldy seed will result in the rejection of the seed for food use. Properly dried and monitored hemp seed can be stored for one to two years without loss of food quality. Hemp seed may need to be stored for up to one year and even into subsequent years while processors source seed from growers to meet production demands. Seeds that undergo heating can be rejected for food use by some processors. The same is true for moldy seeds, which can reduce their value or make them completely unusable. Heating hemp seeds can cause them to oxidize, develop molds, and may scorch seeds. This will reduce the quality and quantity of oil production.

Hemp is usually harvested when the grain has a moisture of 10% to 18%. The wetter the grain, the more urgent the drying process. Aeration and grain dryers can be used for drying seed with frequent turning to avoid hot spots developing. Cold air aeration in cold weather maximizes seed shelf life but will take longer to dry if seed moisture is high. The appropriate moisture level for long term storage of grain hemp is 9- 10% moisture. Regular monitoring of stored grain is essential. It is important to monitor grain dryer temperatures to ensure the seed and seed oil quality is not compromised. Overheating the seed can cause the seed to turn yellow and reduce oil quality. Conversely, low seed moisture that is too low could cause seeds to be prone to cracking during harvest and handling. Hemp seed can rapidly heat, within two to four hours of combining and must be immediately put under aeration or through a dryer to preserve seed quality. Do not allow hemp seed to sit in the truck at the side of the field for more than a few hours before aeration or drying.

Fiber Harvest

Hemp fiber crops can be over 8 ft tall and can reach up to 12 ft. in height. Equipment used for cutting hemp must be able to accommodate this large volume. Standard swathers generally cannot handle hemp fiber crops. Many first-time producers have found that a sickle bar and disc bine work well for cutting hemp for fiber. The goal is to reduce stalk moisture to less than 15% before baling and should continue to dry to about 10% in the bale. With field retting, a considerable time between cutting and baling may be necessary. Experience in Canadian production has shown the length of retting time is normally 21 to 28 days when industrial hemp is cut for fiber during the late summer. Once moisture is under 15 per cent no more retting will take place. Hemp is baled into large round bales or large square bales, depending on processing equipment. If hemp fiber is dried before it’s baled and stored out of the elements, climate-controlled facilities or other special considerations aren’t generally needed. Large bales stored outdoors have the potential to absorb rainfall, and the added moisture can lead to rotting. Fiber bales shouldn’t be stored outdoors under plastic because moisture can wick up from the ground and spoil the bales. Based on experience with hay handling and storage it is suggested that hemp fiber should be stored off the ground to keep the bales from absorbing moisture. As with hay, hemp fiber is sometimes stored on wooden pallets.

APPENDICIES

A. USDA FEDERAL HEMP RULE

Federal Register:: Establishment of a Domestic Hemp Production Program

URL: https://www.federalregister.gov/documents/2019/10/31/2019-23749/establishment-of-a-domestic-hemp-production-program

Hemp Production | Agricultural Marketing Service (usda.gov)

URL: https://www.ams.usda.gov/rules-regulations/hemp

B. NEW JERSEY HEMP RULE – NJ DEPARTMENT OF AGRICULTURE

Department of Agriculture | New Jersey Hemp Program (nj.gov)

URL: https://www.nj.gov/agriculture/news/hottopics/approved/topics190122.html

C. DEA HEMP TESTING LABORATORIES

Any laboratory testing hemp for THC concentration under the U.S. Domestic Hemp Production Program must be registered with the Drug Enforcement Administration (DEA) to handle controlled substances. A directory is provided for informational purposes only and should not be considered an endorsement or recommendation.

Licensed hemp producers should first verify with their licensing body in their state (the NJ Department of Agriculture) to find out where their hemp may be tested.

A listing of DEA approved testing labs can be found at: https://www.ams.usda.gov/rules-regulations/hemp/dea-laboratories

**Since these labs may change or new labs may be added, please use the link for the most recent list of DEA approved testing labs for hemp*.

D. PESTICIDE SAFETY AND APPLICATOR INFORMATION

Pesticide applicators must follow the pesticide label instructions and use pesticides safely. Pesticide applicators are responsible for the proper use of pesticides, residues on crops, storage and disposal, as well as for damage caused by drift. Since State and federal pesticide regulations are constantly under revision, check to determine if such changes apply to your situation. Using pesticides inconsistent with label directions is illegal. Days between the last pesticide application and harvest is termed "Pre-Harvest Interval" or PHI and is generally counted in days. Reentry information on the pesticide label is generally listed as "Restricted Entry Interval" or REI and is usually listed in hours on pesticide labels. It is also important to read the label for other restrictions. Trade or Brand Names mentioned in production guides are supplied with the understanding that no discrimination is intended, and no endorsement is implied.

GENERAL PESTICIDE APPLICATOR INFORMATION:

- NJDEP Pesticide Applicator Information can be found at: https://www.nj.gov/dep/enforcement/pcp/bpo.htm
- Pesticide Exam Study Manuals are available at cost online to order at: https://pestmanagement.rutgers.edu/pat/manuals/
- Pesticide Applicator Exams
    - Pesticide Applicators Exams are administered via Rutgers University. Registration is available online through the PACER system at: https://pacer.rutgers.edu
    - The registration PACER system and exams are available 24/7.
    - All exams will be administered via online/remote proctoring including real-time student ID verification and activity monitoring to uphold the DEP's exam standards and security. May change back to in-person testing in the future.
    - All exams are CLOSED book.
    - Exam applicants need to pay a fee online to Rutgers for each exam.
- Continuing Education Unit Credits (aka Recertification Credits)
    - Once licensed, pesticide applicators must attend educational classes to obtain recertification credits to maintain their licenses. A total of 8 CORE credits and 16 Private or Category credits must be accumulated over a 5-year period to fulfill the recertification requirements for license renewal. Check the NJDEP Website for approved classes providing continuing education unit credits. For courses offered by Rutgers Cooperative Extension see the Rutgers NJAES Events Website.

E. RUTGERS SOIL AND PLANT DIAGNOSTIC TESTING LABS

The Rutgers Soil Testing Laboratory is a part of Rutgers New Jersey Agricultural Experiment Station (NJAES). Located on the G. H. Cook Campus, the Soil Testing Laboratory is a service unit that offers chemical and mechanical analyses of soils.

Rutgers Soil Testing Laboratory
Rutgers, The State University of New Jersey
57 US Highway 1
New Brunswick, NJ 08901-8554
Phone: 848-932-9295
Email: soiltest@njaes.rutgers.edu
Website: https://njaes.rutgers.edu/soil-testing-lab/

The Rutgers Plant Diagnostic Laboratory is a full-service plant health diagnostic facility of Rutgers New Jersey Agricultural Experiment Station (NJAES) and is located near the G.H. Cook Campus. Their mission is to provide accurate and timely diagnoses of plant health problems.

Rutgers Plant Diagnostic Laboratory
Ralph Geiger Turfgrass Education Center
20 Indyk-Engel Way
New Brunswick, NJ 08901
Phone: 732-932-9140
Email: rutgerspdl@njaes.rutgers.edu
Website: https://njaes.rutgers.edu/plant-diagnostic-lab/

F. USDA INFORMATION: HEMP FEDERAL CROP INSURANCE

Hemp Crop Insurance Standards Handbook (usda.gov)