Hemp From Field to Flower: Overcoming Production Challenges in Hemp.
Soil Limitations

• Hemp is widely adapted to many climate

BUT

• Good soil physical properties/soil health

• 40% or more clay not generally good.

• Adequate pH – over 6.0 (requires calcium).
Fertility Requirements

Nitrogen (3.0 to 4.0%)

Potassium (2.0 to 3.0%)
65 – 70 lbs per acre

Phosphorus (0.5 – 0.6%)
50 to 70 lbs per acre
Hemp Nitrogen Fertility

- High N can stimulate the formation of male flowers.

- Split applications of N are best to minimize over feeding at any one single stage.

- A deficiency of N causes the entire hemp plant to turn yellow (chlorosis).

- With deficiency growth and flowering are slowed, and the plants will be mostly male.
## Whole Plant Analysis

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Nitrogen</th>
<th>Calcium</th>
<th>Phosphorus</th>
<th>Magnesium</th>
<th>Potassium</th>
</tr>
</thead>
<tbody>
<tr>
<td>lbs N ac(^{-1})</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
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<tr>
<td>0</td>
<td>2.47 b</td>
<td>2.35 bc</td>
<td>0.625</td>
<td>0.238 c</td>
<td>2.21</td>
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<tr>
<td>75</td>
<td>2.63 b</td>
<td>2.10 c</td>
<td>0.540</td>
<td>0.258 bc</td>
<td>1.96</td>
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<tr>
<td>100</td>
<td>2.66 b</td>
<td>2.38 bc</td>
<td>0.610</td>
<td>0.283 ab</td>
<td>1.93</td>
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<tr>
<td>125</td>
<td>3.25 a</td>
<td>2.83 a</td>
<td>0.620</td>
<td>0.303 a</td>
<td>2.09</td>
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<tr>
<td>150</td>
<td>3.04 a</td>
<td>2.67 ab</td>
<td>0.548</td>
<td>0.308 a</td>
<td>2.10</td>
</tr>
<tr>
<td>LSD (&lt;0.10) ‡</td>
<td>0.378</td>
<td>0.355</td>
<td>NS ¥</td>
<td>0.044</td>
<td>NS</td>
</tr>
<tr>
<td>Trial mean</td>
<td>2.81</td>
<td>2.47</td>
<td>0.589</td>
<td>0.278</td>
<td>2.06</td>
</tr>
</tbody>
</table>

†Within a column, treatments marked with the same letter were statistically similar (p=0.10). Top performers are in **bold**.
‡LSD – Least significant difference at p=0.10.
¥NS – No significant difference between treatments.
CBD Nitrogen fertility – Total CBD & Total THC

<table>
<thead>
<tr>
<th>Nitrogen application rate (lbs/ac)</th>
<th>Total CBD (%)</th>
<th>Total THC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 lbs ac-1</td>
<td>7.34</td>
<td>0.26</td>
</tr>
<tr>
<td>75 lbs ac-1</td>
<td>7.12</td>
<td>0.25</td>
</tr>
<tr>
<td>100 lbs ac-1</td>
<td>8.54</td>
<td>0.30</td>
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<tr>
<td>125 lbs ac-1</td>
<td>7.36</td>
<td>0.26</td>
</tr>
<tr>
<td>150 lbs ac-1</td>
<td>7.24</td>
<td>0.26</td>
</tr>
</tbody>
</table>
Root Ecology

• Long tap root (6 ft) if friable soil.

• Medium texture soil tap root 3 ft.

• High water table more lateral roots.
Fertility Requirements

Potassium (2.5 to 3.0%)
65 – 70 lbs per acre

Phosphorus (0.5 – 0.6%)
50 to 70 lbs per acre
Hemp Phosphorus Fertility

- Hemp growth, fiber yield, and concentration of THC are positively correlated with extractable phosphate.

- Hemp uses 250% more phosphorus at flowering than during the vegetative phase.

- A deficiency of P shows as abnormally dark dull green leaves with a purple tint on the underside, and downward-curling margins.

- Make sure soil test P is optimum or apply P at planting and potentially close to flowering.
Hemp Potassium Fertility

- The absorption of K in hemp is highest in the 4th week after germination.
- An excess of K when flowering occurs, will delay maturity and inhibit essential oil production.
- When hemp is cultivated for essential oil, the supply of K should be reduced by 50% during flowering.
Micronutrient deficiencies often observed in light textured soils that have had low organic matter additions. OR when soil pH is not between 6.0 and 7.0

Hemp has an extraordinarily high requirement for Mg.

Hemp requires 250 grams of boron per acre. Boron tends to be deficient in many VT soils.
Seed Purchase - Buyer Beware

- Male/Female Seed
- High THC
- Mutants/Variation
- Poor Quality
Seed Purchase – Buyer Beware

- NOT COMPLIANT
- Cieba
- Cherry Wine
- Painted Lady
CBD Variety Trial - Yields

Dry matter flower yield (lbs/ac)

CBD hemp variety

V/T Cherry, Cherry Canal, Cosmic, RM13, Cherry Blossom, Boax Wine, Cherry Wine, Boax, Suzy Q, Wolf, Celha, Eighty-Eight, Slipper, AC/DC, Apollo, Dave's Haze, Outback, Alexa, Painted Lady, River Rock
Flower to Leaf in 2020

- **Lifter** 45% flower and 25% leaf

- **Anna Lee** 19% flower and 47% leaf
Approximately 1 month in greenhouse
Deep 72 or 50 cell trays
Potting mix many successes – Fort-V Lite
Seedling Stage Sensitive

Hemp Planted from Seed
2 x 2’ arrangement
1500 lbs DM acre

47% Germ June 17th 2019
72% Germ July 24th 2019
Transplanting Hemp
Transplanting Hemp
Transplanting into Ryegrass
Plastic Mulch
Transplanting Hemp
Transplanting Hemp
Hemp and Plasticulture
CBD Plant Spacing x Planting Date Trial (var. Ceiba)

Marketable and unmarketable flower yields by spacing: per acre basis

Treatments with the same letter are statistically similar at the 0.10 level.
CBD Plant Spacing x Planting Date Trial (var. Ceiba)

Flower dry matter yields and total potential CBD by plant spacing

Treatments with the same letter are statistically similar at the 0.10 level.
CBD Plant Spacing x Planting Date Trial (var. Ceiba)

Marketable and unmarketable flower yields by spacing: per plant basis

Treatments with the same letter are statistically similar at the 0.10 level.
CBD Plant Spacing x Planting Date Trial (var. Ceiba)

Biomass percentages by plant spacing
Powdery mildew on a 1 x 1 spacing plant
CBD Plant Spacing x Planting Date Trial (var. Ceiba)

Flower dry matter yields and total potential CBD by planting date

Treatments with the same letter are statistically similar at the 0.10 level.
CBD Plant Spacing x Planting Date Trial (var. Ceiba)

Biomass percentages by planting date

10-Jun
- Stem: 47%
- Leaf: 28%
- Bud: 25%

24-Jun
- Stem: 57%
- Leaf: 22%
- Bud: 21%

17-Jun
- Stem: 50%
- Leaf: 24%
- Bud: 26%
Hemp Drought Resistant BUT

- Hemp requires at least 20-30 inches of rainfall during the growing period.
- Abundant moisture is needed during the germination period.
- The absorption of water increases until flowering begins. First 6 - 8 weeks of growth.
- Then the uptake of water decreases considerably, with a slight increase at late flowering and during seed formation.
Water Requirements

• There is a significant correlation between soil moisture and cannabinoid content. THC & CBD indicated to increase with decreasing moisture and humidity. (Latta and Eaton, 1975; Sikors et al., 2011)

• Hemp requires a plentiful supply of moisture throughout its growing season, especially during the first 6 weeks.

• After it has become well rooted and the stalks are 20 to 30 inches high it will endure drier conditions, but a severe drought hastens its maturity and tends to dwarf its growth.

• In puddled areas of a saturated field hemp will be stunted in two days.
We Should Water Because We Have Irrigation?
Irrigation?

Impact of Irrigation on Bud Yield

- Rain-fed
- Irrigation
**Cover Crops**
Lack of Crop Rotation

- Hemp is susceptible to many diseases.
- Hemp should be rotated ideally every 2 years.
- To minimize disease build-up would recommend a 4 to 6 year rotation.
Septoria leaf spot

More common outdoors

Provide adequate plant spacing

Avoid splashing soil on leaves

Use of plastic mulches can help

Destroy effected plant debris at season's end
Powdery Mildew

Less likely to survive without host

Found on upper surface of leaf

Good air flow is important

Favored by moderate temperature and high humidity

Much bigger issue indoors

Select resistance varieties
Powdery Mildew progression
Botrytis (Grey Mold)
Sclerotinia (White Mold)

Can survive in soil for more than 2 years

Also attacks many broadleaf crops and weeds

Rotate with non-host crops such as cereals

Broadleaf weeds must be suppressed

• **Actinovate** (Novozymes BioAg Inc., EPA Reg. No. 73314-1) - *Streptomyces lydicus*
  Suppress or control foliar fungal, root rot, and damping off pathogens. This product is labeled for use against downy mildew and other pathogens. Works best if it is used prior to disease onset.

• **Cease** (Bioworks Inc., EPA Reg. No. 264-1155-68539) - *Bacillus subtilis*
  This product can be used to control a variety of fungal pathogens and bacterial diseases and is intended for use as both a foliar spray and a soil drench. Cease is to be used at the onset of favorable disease conditions prior to the onset of symptoms.

• **Regalia** (Marrone Bio Innovations, EPA Reg. No. 84059-3) – *Fallopia sachalinensis* (giant knotweed)
  Is a broad-spectrum bio-fungicide that is active against soil borne and foliar pathogens. Regalia works by stimulating the plant’s natural defenses and has antifungal and antibacterial properties.

• **Trifecta Crop Control** (Trifecta LLC, EPA/FIFRA exempt (25b) insecticide/fungicide)
  A nano-emulsified essential oil based multi-purpose mold, mildew and pest control. The active ingredients include soap, isopropyl alcohol, thyme oil, clove oil, garlic oil, vinegar, peppermint oil, corn oil, geraniol, citric acid and rosemary oil. Trifecta uses the various essential oils to act as a repellent, suffocant, reproductive inhibitor, and fungicide and can be applied directly to foliage or as a soil drench depending on target pest.
Figure 1. Unmarketable flower (%) at harvest by fungicide treatment, Alburgh, VT, 2019.
Products – 2021/2022

- **Cease:** *Bacillus subtilis*
- **Double Nickel LC:** *Bacillus amyloliquefaciens*
- **Oxidate:** Hydrogen Peroxide & Peroxyacetic Acid
- **Kocide 3000:** Copper Hydroxide *(not approved)*

Applied starting of flower and applied until harvest. Rates were based on label.
## Fungicide 2021

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Low Tunnel</th>
<th>Field</th>
<th>Overall</th>
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<tbody>
<tr>
<td></td>
<td>Incidence</td>
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<tr>
<td></td>
<td>Shoots</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>assessed</td>
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<tr>
<td></td>
<td>%</td>
<td></td>
<td></td>
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<tr>
<td>Kocide-3000</td>
<td>0.00 a</td>
<td>40.0 a</td>
<td>21.1 a</td>
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<td>18</td>
<td>20</td>
<td>38</td>
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<td></td>
<td>19</td>
<td>19</td>
<td>38</td>
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<td>Double Nickel</td>
<td>10.0 a</td>
<td>36.8 a</td>
<td>23.1 a</td>
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<td>20</td>
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<td>Cease</td>
<td>5.00 a</td>
<td>35.0 a</td>
<td>20.0 a</td>
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<td>20</td>
<td>20</td>
<td>40</td>
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<td>Water</td>
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<td>20</td>
<td>20</td>
<td>40</td>
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<tr>
<td>Overall</td>
<td>6.19 a</td>
<td>37.8 b</td>
<td>22.1 a</td>
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<td></td>
<td>97</td>
<td>98</td>
<td>195</td>
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Fungicide 2021

<table>
<thead>
<tr>
<th>Location</th>
<th>Fungicide</th>
<th>Copper content</th>
<th>Aerobic microbial count</th>
<th>Combined yeast and mold counts</th>
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</thead>
<tbody>
<tr>
<td>Low Tunnel</td>
<td>Double Nickel</td>
<td>16.88</td>
<td>33,350</td>
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<td>Field</td>
<td>Double Nickel</td>
<td>12.49</td>
<td>6,164</td>
<td>27,562</td>
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<td>Low Tunnel</td>
<td>Kocide 3000</td>
<td>408.1</td>
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<td>184</td>
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<td>Low Tunnel</td>
<td>Control</td>
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<td>92</td>
<td>6,525</td>
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<td>Field</td>
<td>Control</td>
<td>15.76</td>
<td>&lt;LOQ†</td>
<td>3,600</td>
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</tbody>
</table>

Aerobic counts – 100,000 cfu
Yeasts/molds – 10,000 cfu
Fungicide - 2022

• Wetter season

Table 2. p-values for one-way Steel's Test against water control, *significant at p<0.05, indicating that only Double Nickel application significantly controlled the leaf spot disease compared to the water control.

<table>
<thead>
<tr>
<th></th>
<th>bud rot</th>
<th>leaf spot</th>
<th>powdery mildew</th>
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</thead>
<tbody>
<tr>
<td>Cease</td>
<td>0.9076</td>
<td>0.4739</td>
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<tr>
<td>Oxidate</td>
<td>0.9149</td>
<td>0.9038</td>
<td>0.7161</td>
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<td>Kocide</td>
<td>0.9980</td>
<td>0.0602</td>
<td>0.9433</td>
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<tr>
<td>Double Nickel</td>
<td>0.5919</td>
<td>0.0204*</td>
<td>1.0000</td>
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</tbody>
</table>
Fungicide - 2022

• On-Farm Study

  • **Organocide** (Organic Laboratories, Inc. EPA Reg. No. 71962-1-70179) - *Mono &di-potassium salts of Phosphorus acids*
    This is a systemic fungicide to labeled to control a broad array of fungus.

  • **Cease** (Bioworks Inc., EPA Reg. No. 264-1155-68539) - *Bacillus subtilis*
    This product can be used to control a variety of fungal pathogens and bacterial diseases and is intended for use as both a foliar spray and a soil drench. Cease is to be used at the onset of favorable disease conditions prior to the onset of symptoms.

  • **Regalia** (Marrone Bio Innovations, EPA Reg. No. 84059-3) – *Fallopia sachalinensis* (giant knotweed)
    Is a broad-spectrum bio-fungicide that is active against soil borne and foliar pathogens. Regalia works by stimulating the plant’s natural defenses and has antifungal and antibacterial properties.

  • **Milstop** (BioWorks Inc., EPA Reg. No. 68539- ) – Potassium Bicarbonate
    For the control of powdery mildew and other diseases on terrestrial and indoor ornamental plants, greenhouse and agricultural crops.
On-Farm Study

Hawaiian Haze – Started to spray on 8/17/22

Milstop – 0-1% severity
Control – 5-20% severity
Organocide – 10-20% severity

Cease, Regalia fell in between Milstop and Organocide.
Pythium Root Rot

- More common indoors
- Outer root cortex slides off
- Issue for seedlings and transplants
- Pythium can also cause Damping Off
A Season of Pests

<table>
<thead>
<tr>
<th>Month</th>
<th>Aphids</th>
<th>Two Spotted Spider Mites</th>
<th>Potato Leafhopper</th>
<th>European Corn Borer</th>
<th>Japanese Beetles</th>
<th>Flea Beetles</th>
<th>Thrips</th>
<th>Lygus</th>
<th>Hemp Russet Mite</th>
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<tbody>
<tr>
<td>June</td>
<td></td>
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<td>August</td>
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<td>September</td>
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<td></td>
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</tr>
</tbody>
</table>

*Hemp Russet Mite"
European Corn Borers

Hemp is not preferred host

Damage to stalks and stems causing them to break

peak 1st flight late June to early July in VT

If enough degree-day accumulation, 2nd flight in Aug.

Second flight can cause damage to buds

Photo credit: Smith, Auburn University, Bugwood.org.
Cannabis aphid (other aphids)

Found on leaves and stems

Winged and wingless forms

Change color later in season (cream/light green to pale pink to light brown)

Feed on fluid in phloem (often little to no leaf symptoms)

Populations slowly grow as the season progresses

High populations cause reduce plant vigor, slow growth, wilting and leaf yellowing

https://webdoc.agsci.colostate.edu/hempinsects/PDFs/Cannabis%20aphid%20October%202018%20revision%20(1).pdf
Two Spotted Spider Mites

Very small (often on leaf undersides)
Bodies are straw color to green
Pair of large, dark spots on each side of body
Cast skins and eggs (and egg shells) are distinctive

Leaf flecking symptoms on leaves
Extensive webbing may be visible when infestation is severe
Populations explode during hot and dry conditions

https://webdoc.agsci.colostate.edu/hempinsects/PDFs/Twospotted%20spider%20mite%20with%20photos.pdf
Hemp Russet Mite

Not yet known in Vermont

Minute in size (require 15-20 X mag.) Mostly on leaf underside; may develop on stems

Leaves can become small and brittle; can cause bronze/gold color. slight upward rolling may occur

Most damage on developing buds

In severe infestations leaves become a duller color (appear slight gray or bronze) and growth suppressed

https://webdoc.agsci.colostate.edu/hempinsects/PDFs/Hemp%20Russet%20Mite%20Revision%20December%202018.pdf
CBD Variety Trial – Aphid populations

![CBD Variety Trial - Aphid populations diagram](image-url)
Crop Rotation

- Hemp is susceptible to many diseases.

- Hemp should be rotated ideally to a new spot every 1 to 2 years.

- To minimize disease build-up would recommend a 4 to 6 year rotation.
Removing Male Plants

• Male plants must be removed from hemp fields being grown for resins, essential oils, etc.

• The female flowers are highest in these compounds and pollination with subsequent seed production lowers the value.
Removing Male Plants

• Non-feminized seed will result in some male plants (30 to 50% of population).

• Feminized seed can still result in male plants.

• Female plants can have male flowers and these will produce pollen (hermaphrodites).
Removing Male Plants

- Need to constantly be scouting the field for males!
- This starts when the reproductive stage is initiated.
- This is generally starts during the month of August but obviously depends on the variety.
- Auto-flower types do not respond to daylength.
Removing Male Plants

• Practice makes perfect – will learn how to identify male plants as you become more experienced.

• When in doubt pull it out of the field!

Gofarmhemp.com
Figure 1. Average hourly temperatures at the base of the plants in row covered plots and uncovered plots.
Effect of Temperature on Potential CBD

Table 3. Total potential cannabidiol by treatment and average temperature, Alburgh, 2018.

<table>
<thead>
<tr>
<th>Date</th>
<th>18-Oct</th>
<th>19-Oct</th>
<th>21-Oct</th>
<th>22-Oct</th>
<th>24-Oct</th>
<th>26-Oct</th>
<th>Average</th>
<th>Temperature (°F)</th>
<th>Trial average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row cover</td>
<td>9.36</td>
<td>7.55</td>
<td>8.97</td>
<td>11.0</td>
<td>10.3</td>
<td>7.28</td>
<td>9.06</td>
<td>42.3</td>
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</tr>
<tr>
<td>No row cover</td>
<td>9.72</td>
<td>9.13</td>
<td>6.97</td>
<td>11.3</td>
<td>10.5</td>
<td>8.88</td>
<td>9.41</td>
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<tr>
<td>LSD (0.10)</td>
<td>NS</td>
<td>NS</td>
<td>1.46</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>1.94</td>
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</tr>
<tr>
<td>Trial Mean</td>
<td>8.54</td>
<td>8.34</td>
<td>7.97</td>
<td>11.1</td>
<td>10.4</td>
<td>8.08</td>
<td>9.23</td>
<td>40.9</td>
<td></td>
</tr>
</tbody>
</table>

LSD – Least significant difference.
NS – No significant difference in severity between treatments.
Harvest Timing
## Drying Temperature

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Whole stem total potential CBD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
</tr>
<tr>
<td>80°F</td>
<td>7.51</td>
</tr>
<tr>
<td>105°F</td>
<td>6.89</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>7.71</td>
</tr>
<tr>
<td>LSD (0.10)</td>
<td>NS</td>
</tr>
<tr>
<td>Trial Mean</td>
<td>7.21</td>
</tr>
</tbody>
</table>
Storage Temperature

- Freezer
- Fridge
- Air Temp

30 days vs 120 days
Thank You

https://www.go.uvm.edu/nwcrops/hemp