

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

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Professor of Agronomy

March 8, 2023



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



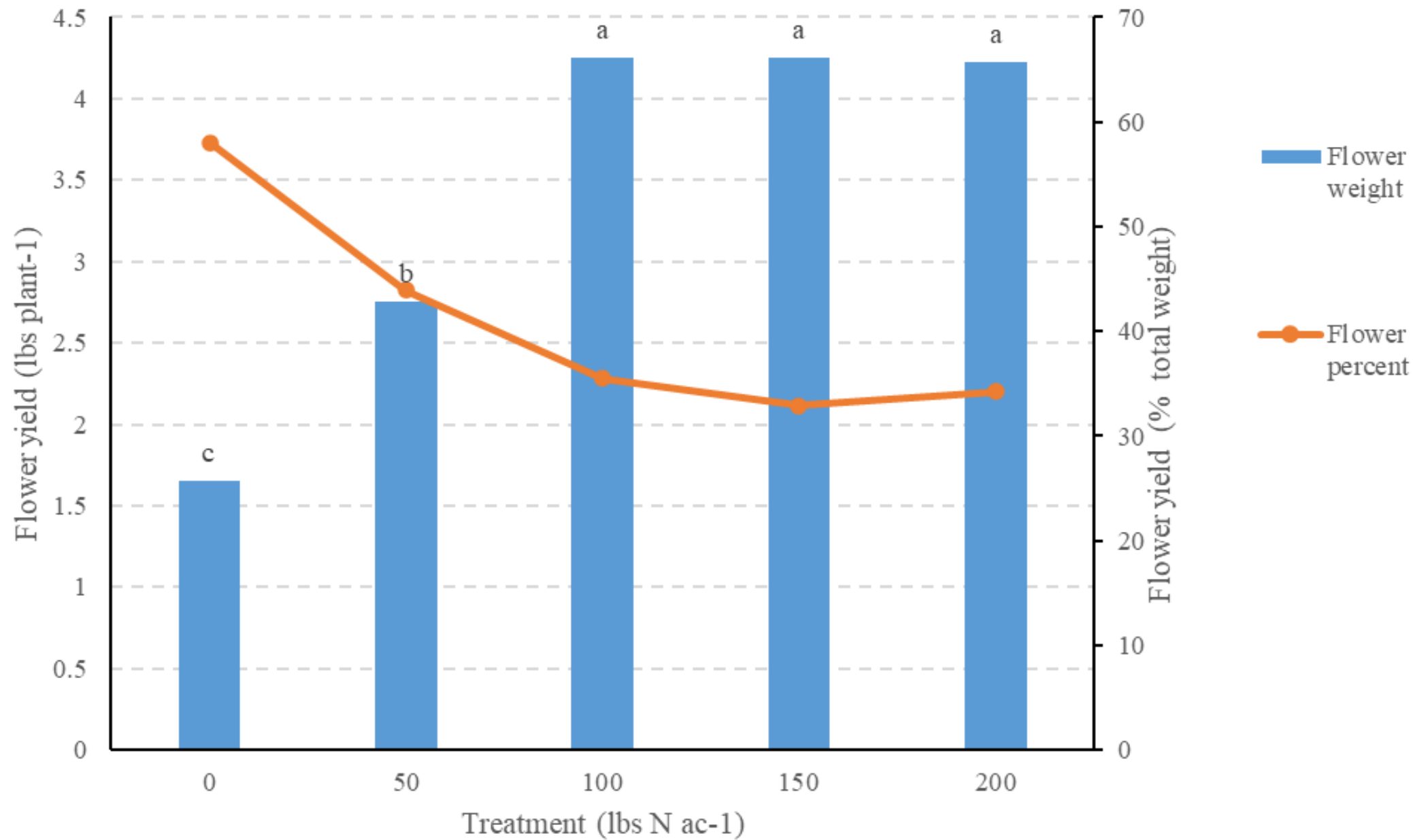
Hemp Nitrogen Fertility

- 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.

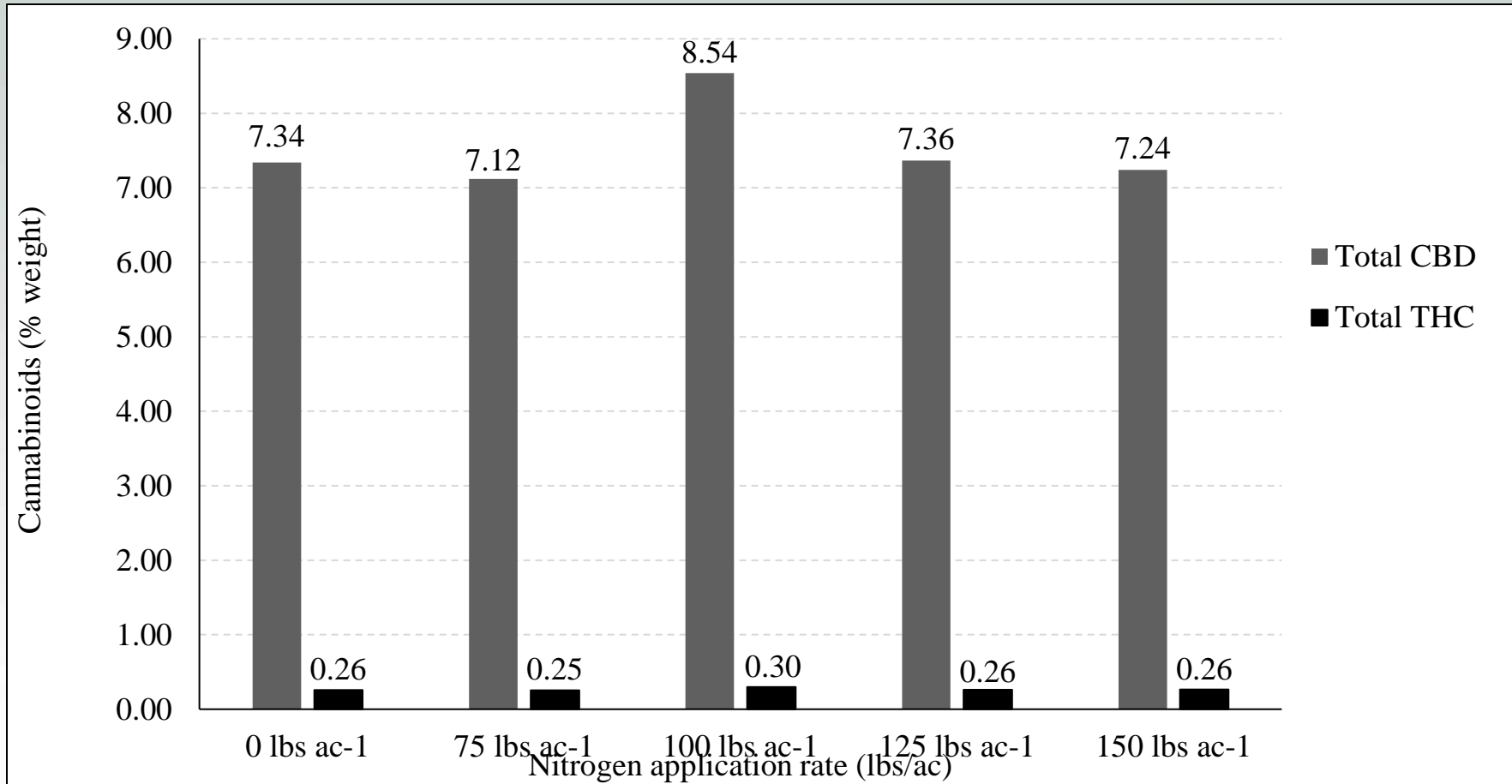
Whole Plant Analysis

Treatment	Nitrogen	Calcium	Phosphorus	Magnesium	Potassium
lbs N ac ⁻¹	%	%	%	%	%
0	2.47 b	2.35 bc	0.625	0.238 c	2.21
75	2.63 b	2.10 c	0.540	0.258 bc	1.96
100	2.66 b	2.38 bc	0.610	0.283 ab	1.93
125	3.25 a	2.83 a	0.620	0.303 a	2.09
150	3.04 a	2.67 ab	0.548	0.308 a	2.10
LSD (<0.10) ‡	0.378	0.355	NS ¥	0.044	NS
Trial mean	2.81	2.47	0.589	0.278	2.06

†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.



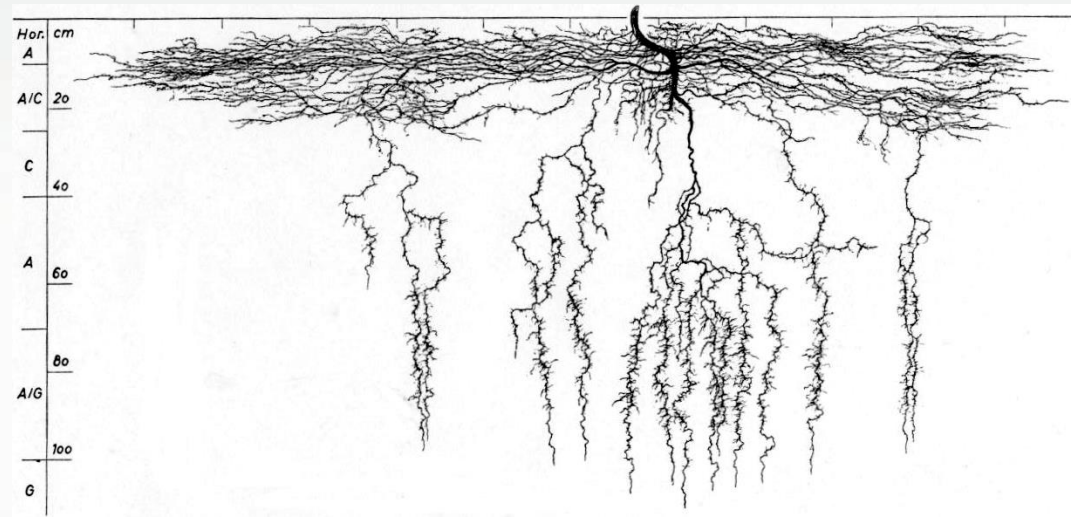
CBD Nitrogen fertility – Total CBD & Total THC





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-curved 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.

Hemp Micronutrient Fertility

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.

Table 2.3
Symptoms of Nutrient Deficiency/Excess

LEAVES

Copper-brown (+N); Copper mottling (-K)	
Curl (+N, -Mg)	
Dead areas (+N)	
Green, dull dark (-P); pale (-S)	
Margins:	
Brown (-K)	Curled, grey (-K)
Downward-curl (-P)	Yellow (-Ca, -Mg, -Fe)
New Leaves:	
Brown & white spots (-Ca)	Chlorosis (-Fe)
Dark (-Ca)	Grey-brown & dying (-B)
Grey-white spots (-Fe)	Yellow edges (-Fe)
Yellow & dying (-K)	
Old Leaves:	
Chlorosis (-Mg)	Yellow (-Mo)
Dark-grey (-K)	
Pimples (+N)	
Purple (-B); Purple on underside (-P)	
Spots:	
Grey-brown necrotic (-Mn)	Grey-white patches (-Mg)
White (+K)	Dark (-K)
Twisted (-Zn)	
Veins:	
Blackening around (+Ca)	Bleaching between veins (-K)
Chlorosis between veins (-Zn)	Pulpy (+N)
Purple (-S)	Varicose (-Mg)
Yellow between veins (+N, -Mo);	Yellow with green margins (-Mn)
Yellow-coppery areas, dying leaves (+Water)	
Wilting (+N)	

STEMS

Brittle (-Ca)
Brown (+N)
Cracked (-B)
Dark areas (-Ca)
Dry rot (-B)
Herbaceous (-K, +N, +K, +Ca)
Hollow females (-Mg); Hollow males (-K, +N, +K, +Ca)
Reddish, then black (-P)
Solid females (-K)
Weak, broken (-Cu)

MERISTEMS

Stunted (+K, +Ca, -Mn)

GENERAL GROWTH

Stunted, flabby (-Ca, -Mn, -B)

Seed Purchase - Buyer Beware

- Male/Female Seed
- High THC
- Mutants/Variation
- Poor Quality

MW Labs
724 S Central Ave STE 202
Medford OR 97501
(541) 499-6300
License: 1008606C050

Certificate of Analysis
Sample ID: HEMPRESS2
Report ID: TR- HEMPRESS2

Client Name: CBDINC
License No: N/A
Address: N/A

Date Sampled: Submitted on 2/20/2019
Sampled by: Client
Sample Name: HEMPRESS2
Sample Type: FLOWER
Sample Weight: N/A

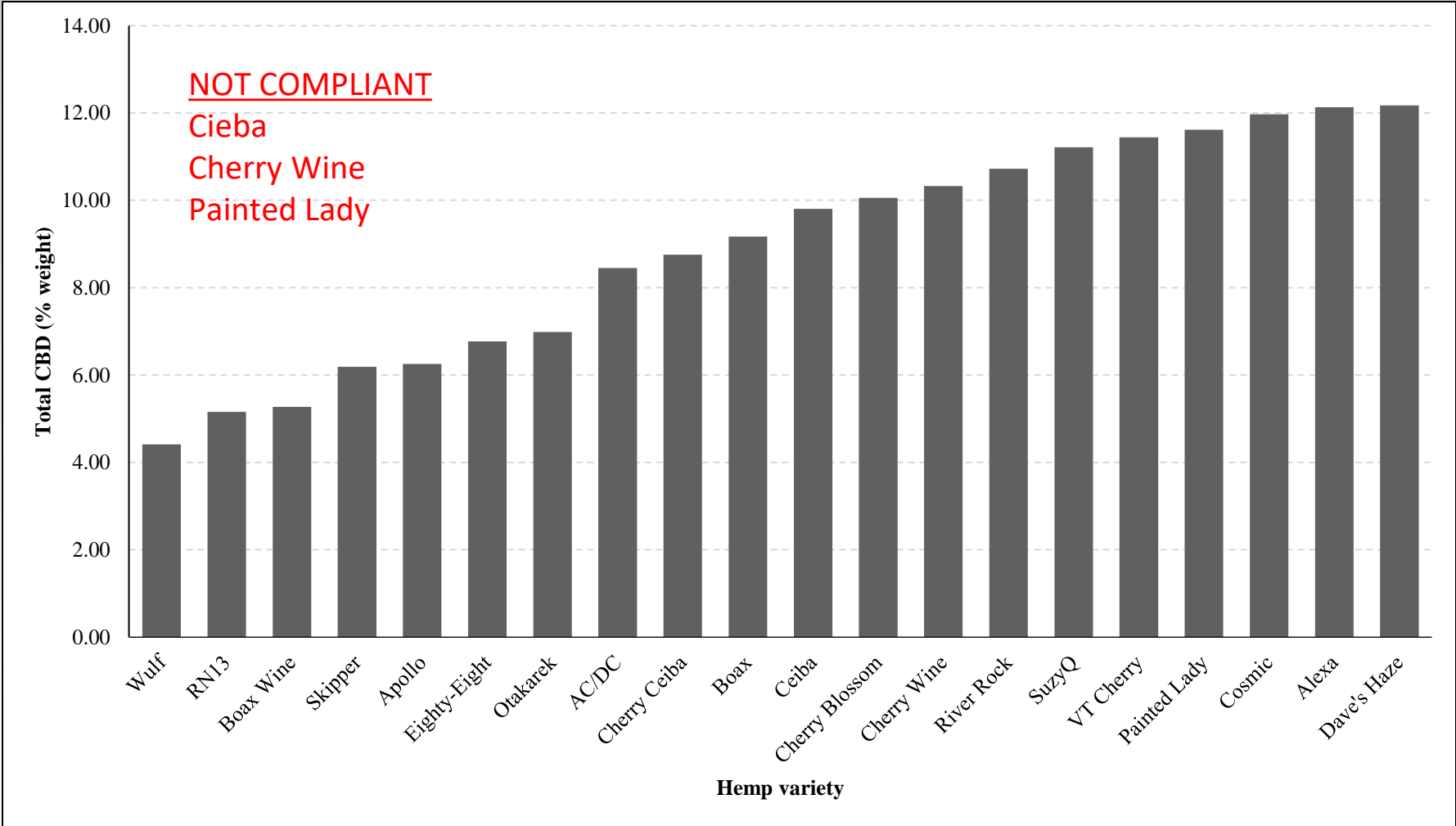
Description of the sample and environmental conditions. Interpretation of the results. Sample appeared normal under environmental conditions. Interpretation of the results.

Summary of Test Results

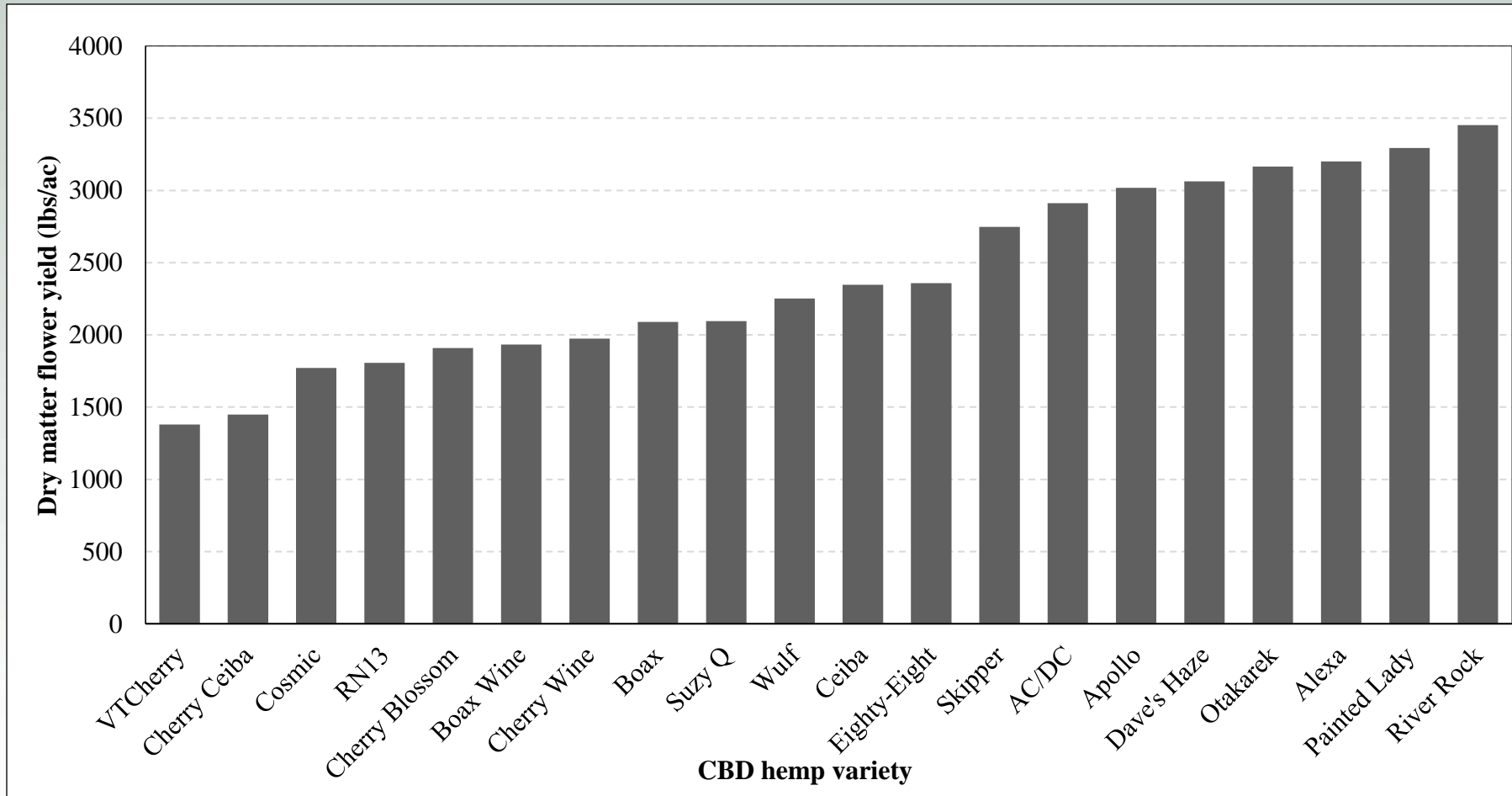
Items	Value
Total THC:	0.29 %
Total CBD:	17.1 %

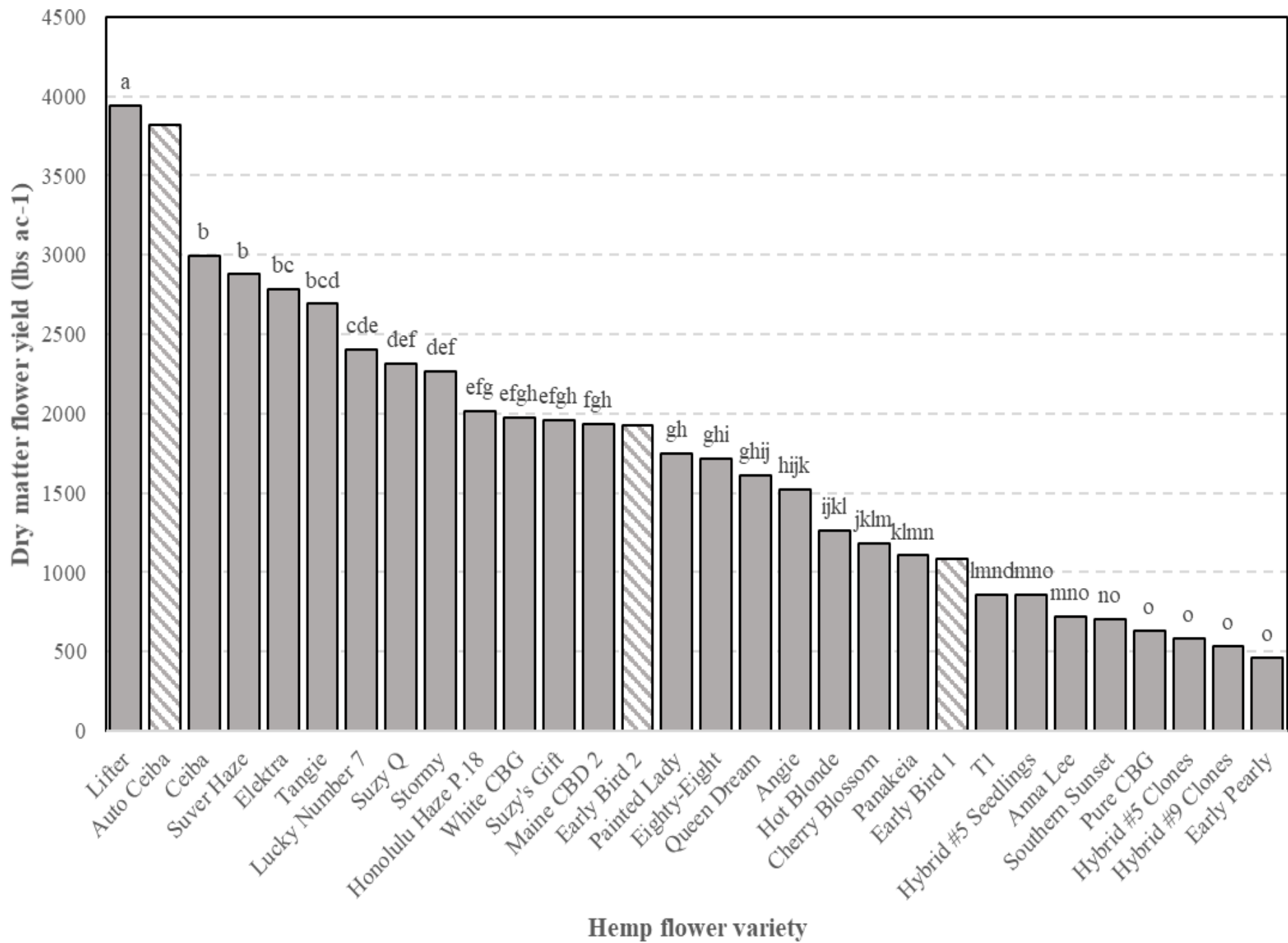


Seed Purchase – Buyer Beware



CBD Variety Trial - Yields





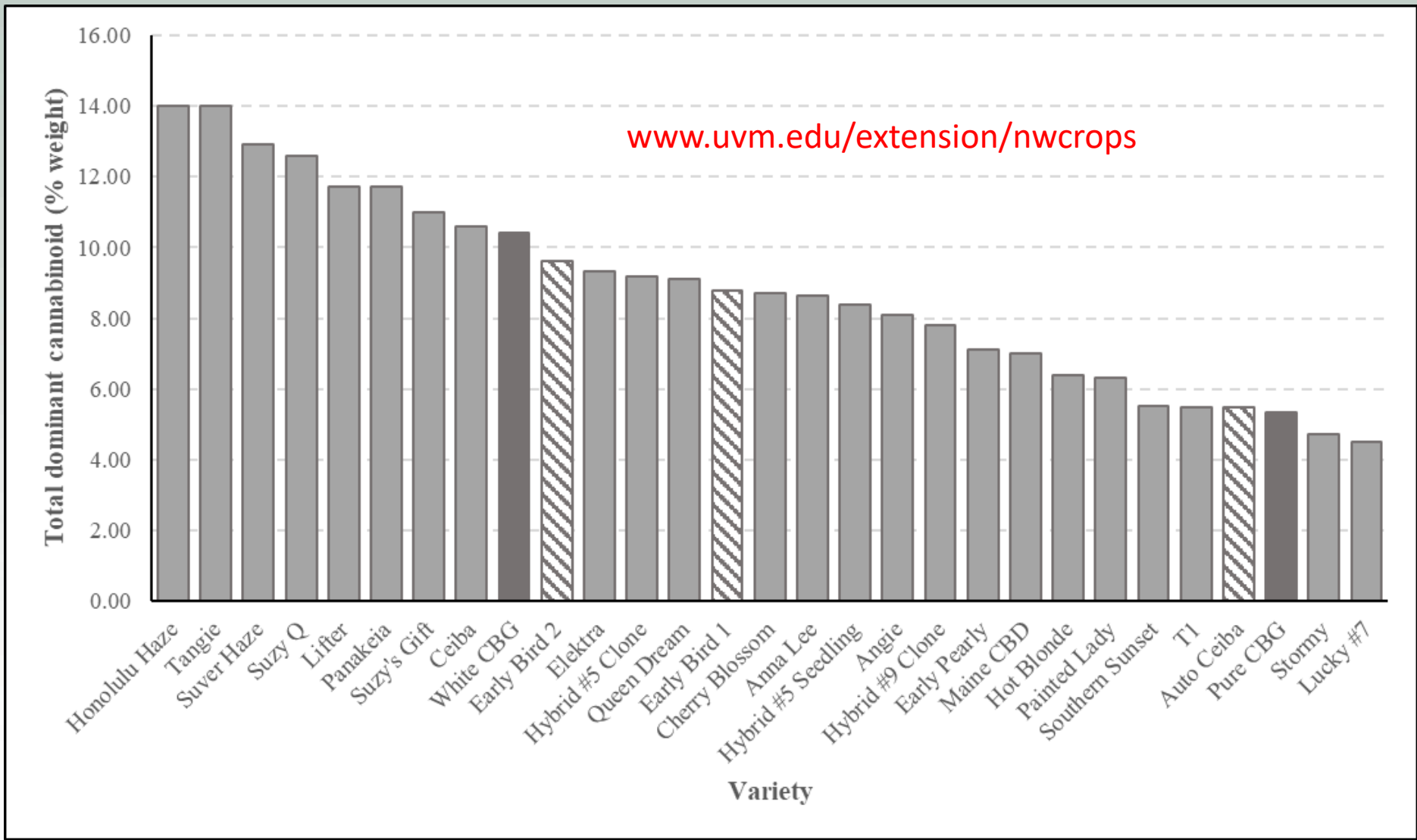
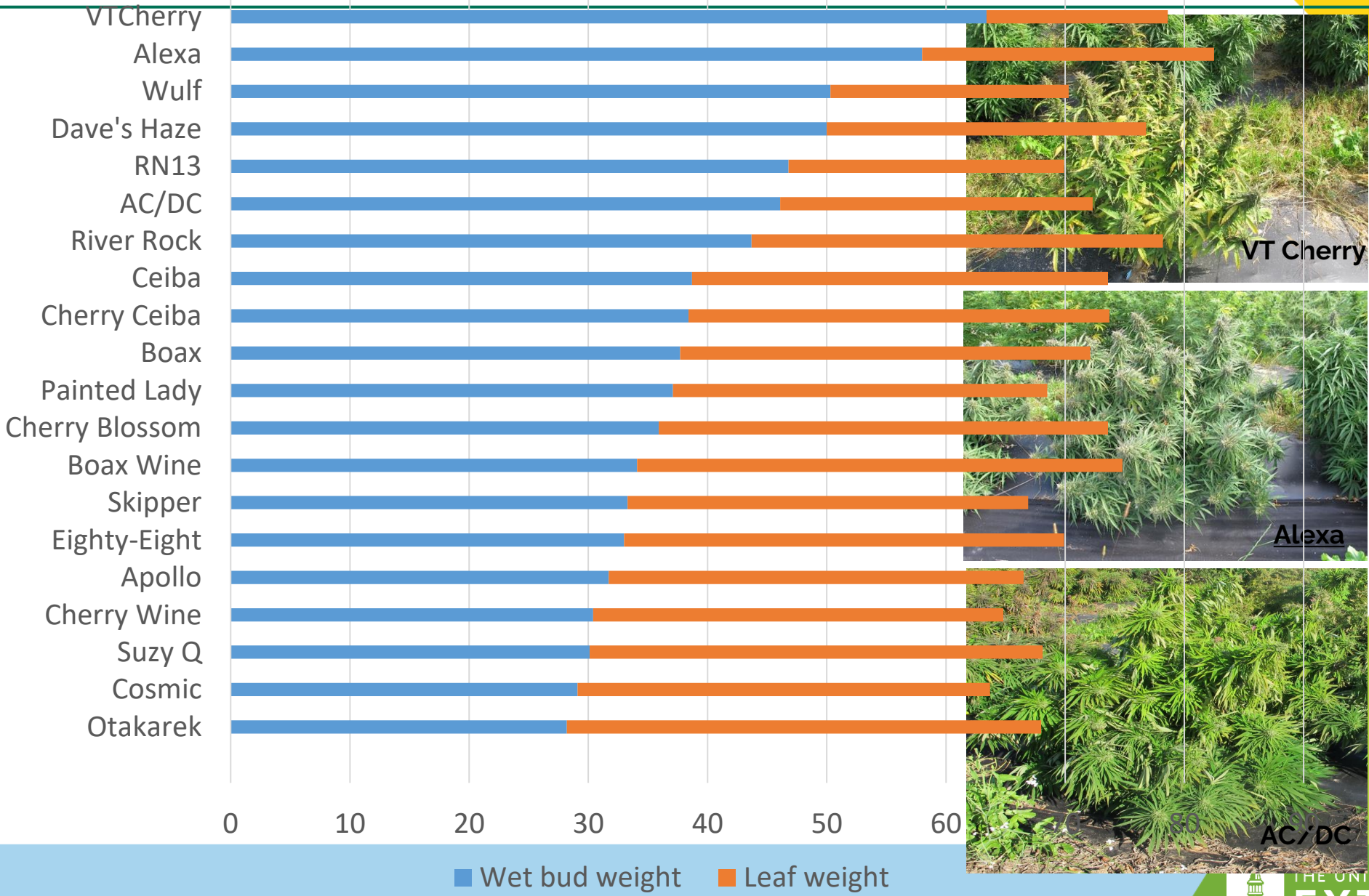


Chart Title



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







3 11 4

Transplanting Hemp



Transplanting Hemp

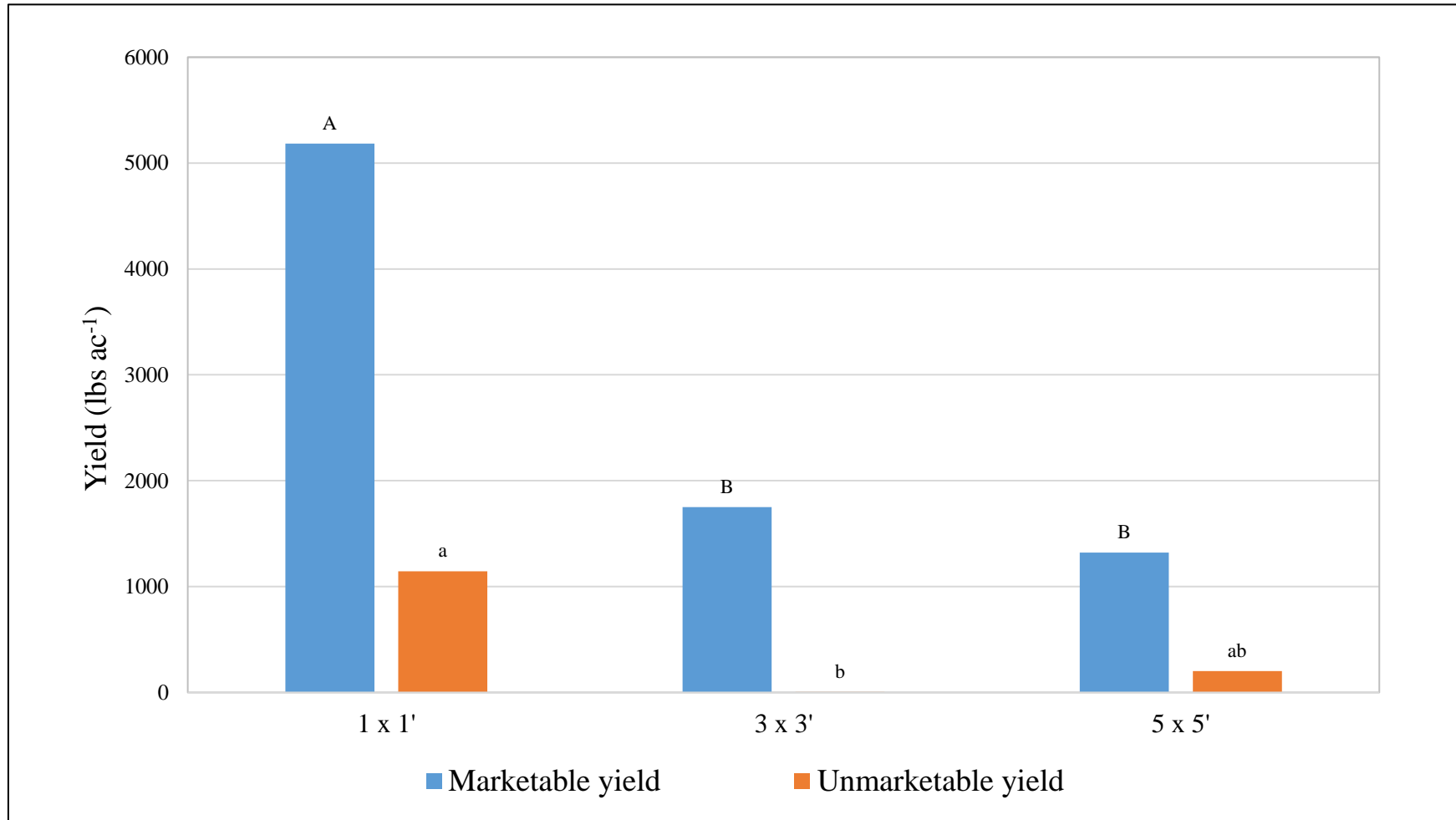


Hemp and Plasticulture



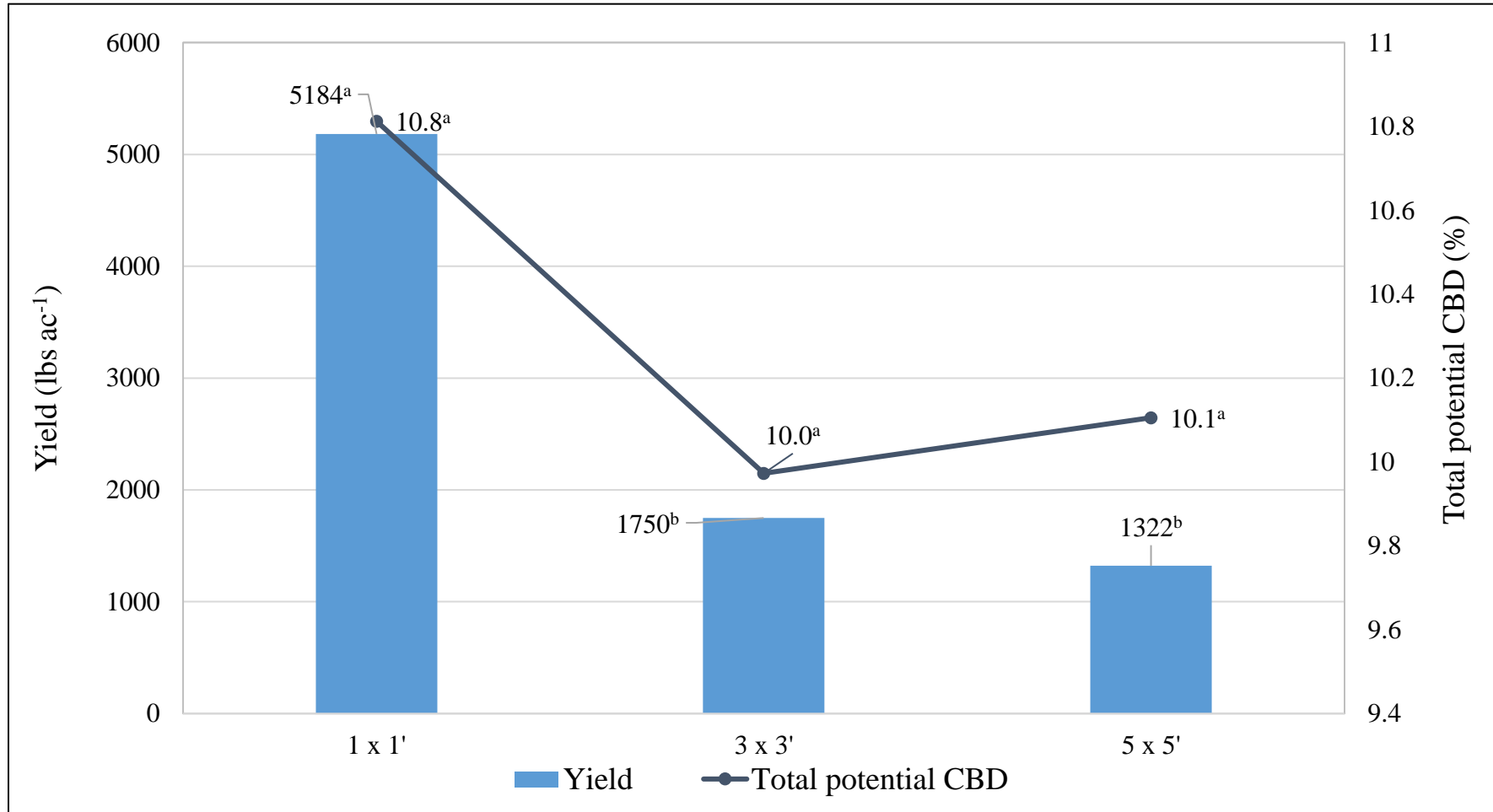


Marketable and unmarketable flower yields by spacing: per acre basis



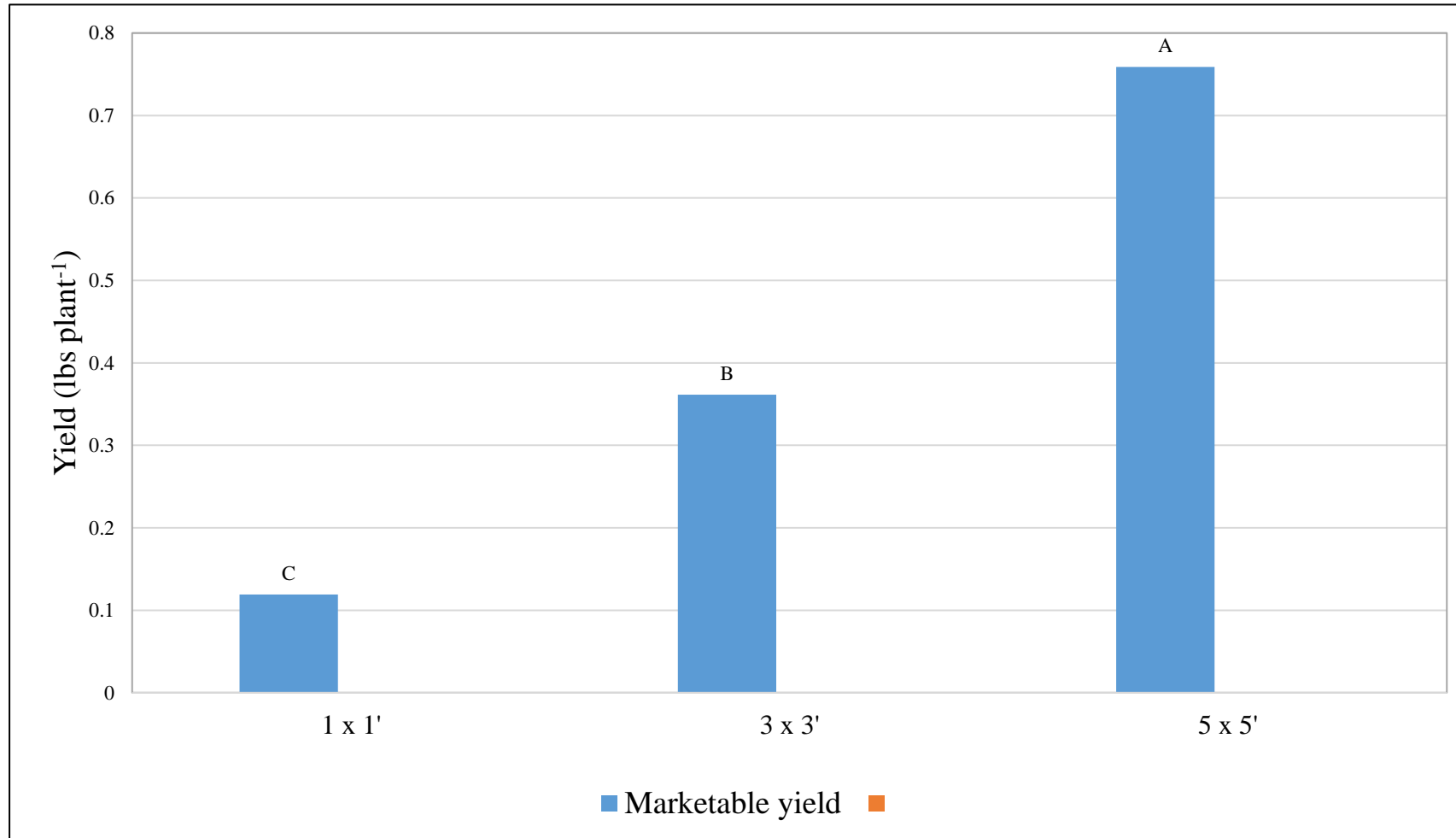
Treatments with the same letter are statistically similar at the 0.10 level.

Flower dry matter yields and total potential CBD by plant spacing



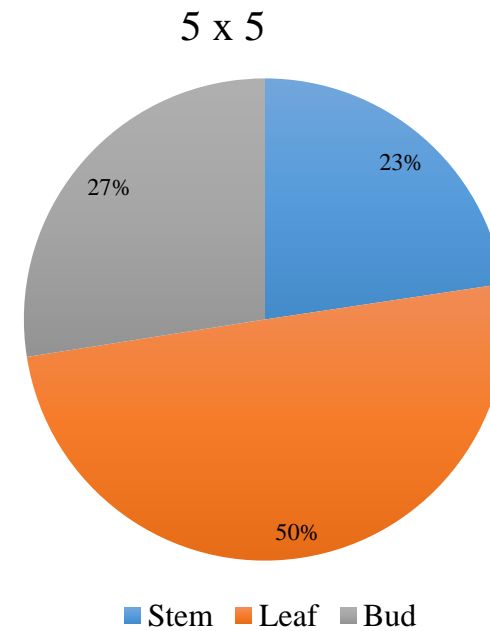
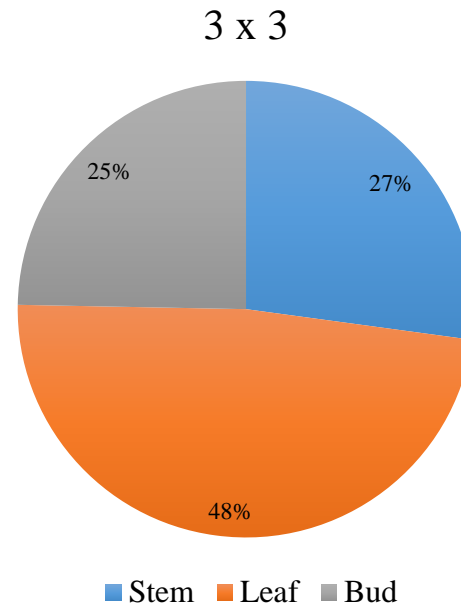
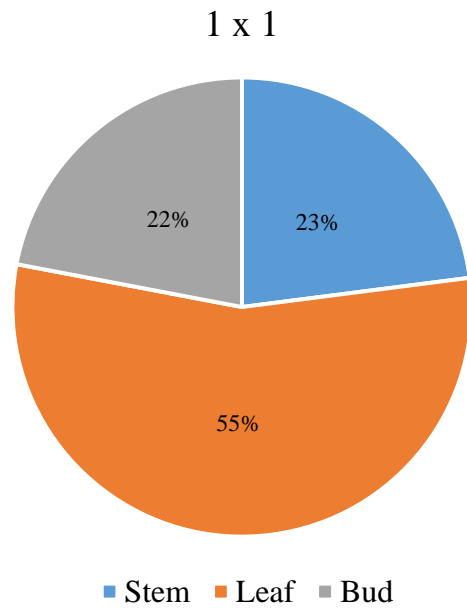
Treatments with the same letter are statistically similar at the 0.10 level.

Marketable and unmarketable flower yields by spacing: per plant basis



Treatments with the same letter are statistically similar at the 0.10 level.

Biomass percentages by plant spacing

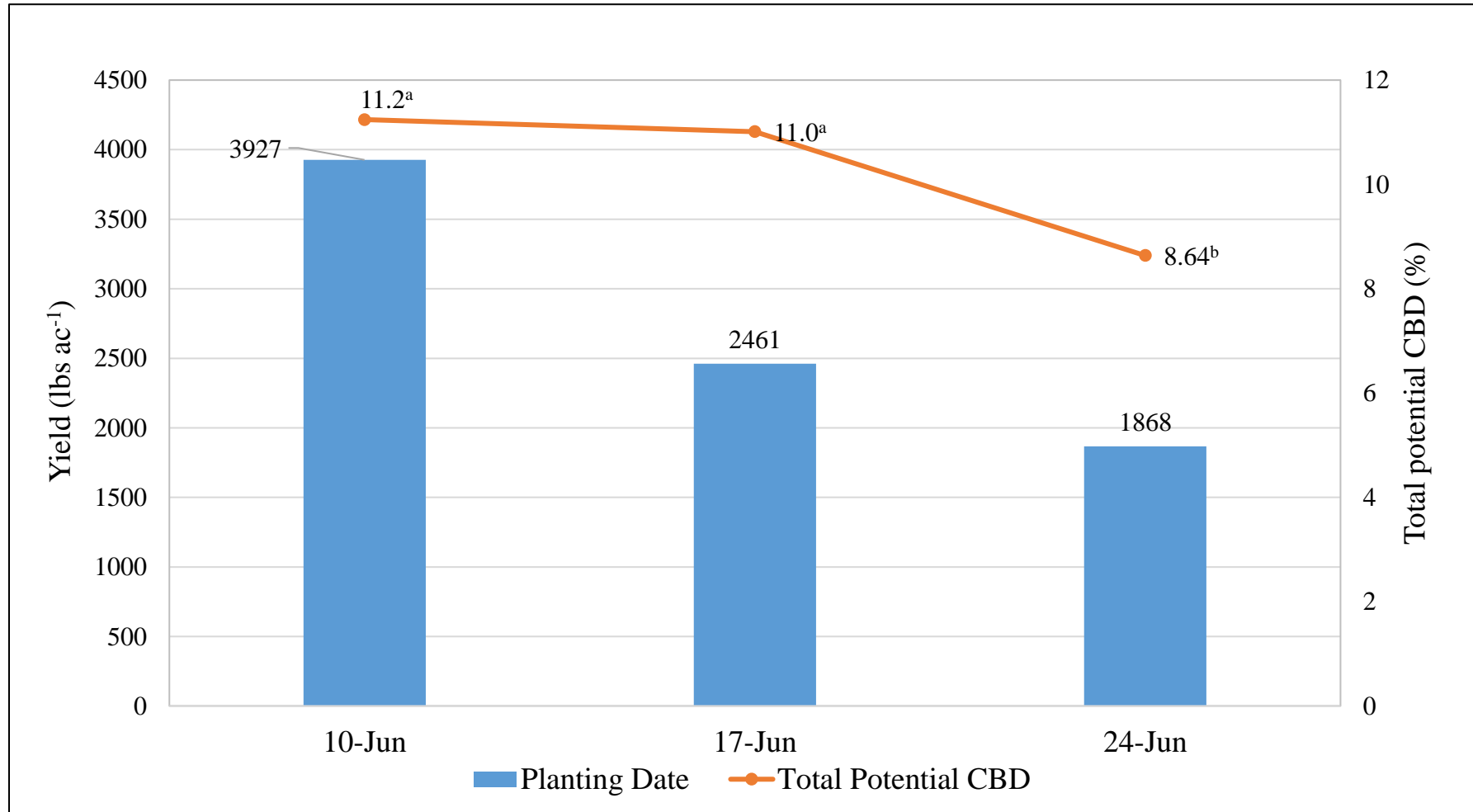




Powdery mildew on a
1 x 1 spacing plant

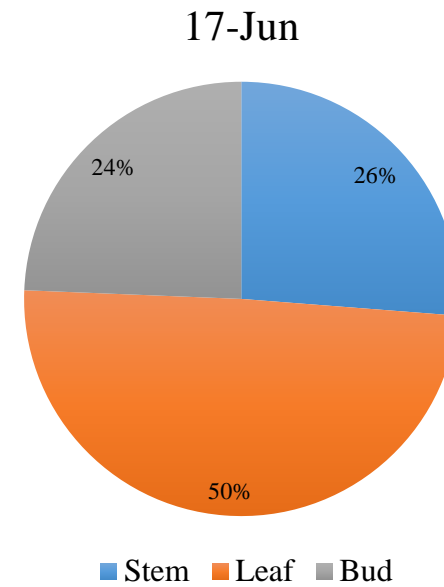
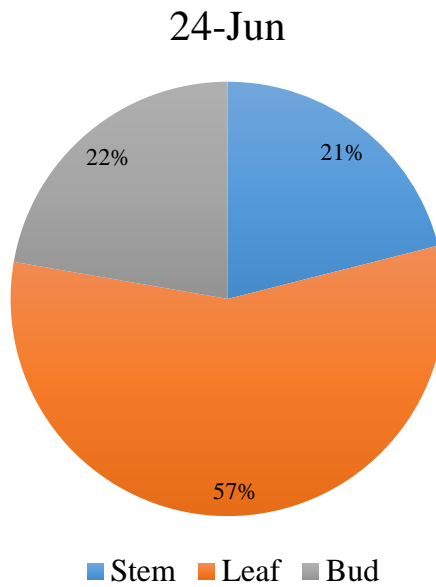
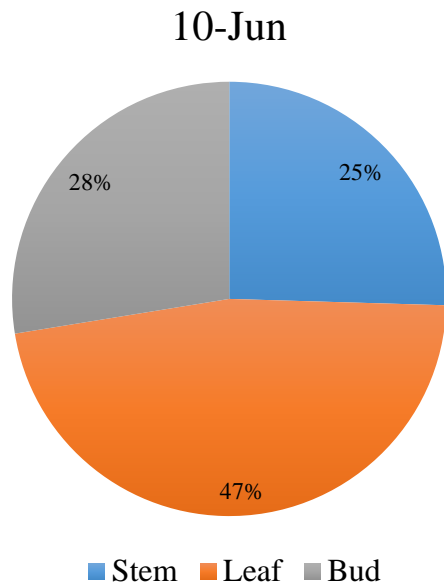
CBD Plant Spacing x Planting Date Trial (var. Ceiba)

Flower dry matter yields and total potential CBD by planting date



Treatments with the same letter are statistically similar at the 0.10 level.

Biomass percentages by planting date



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

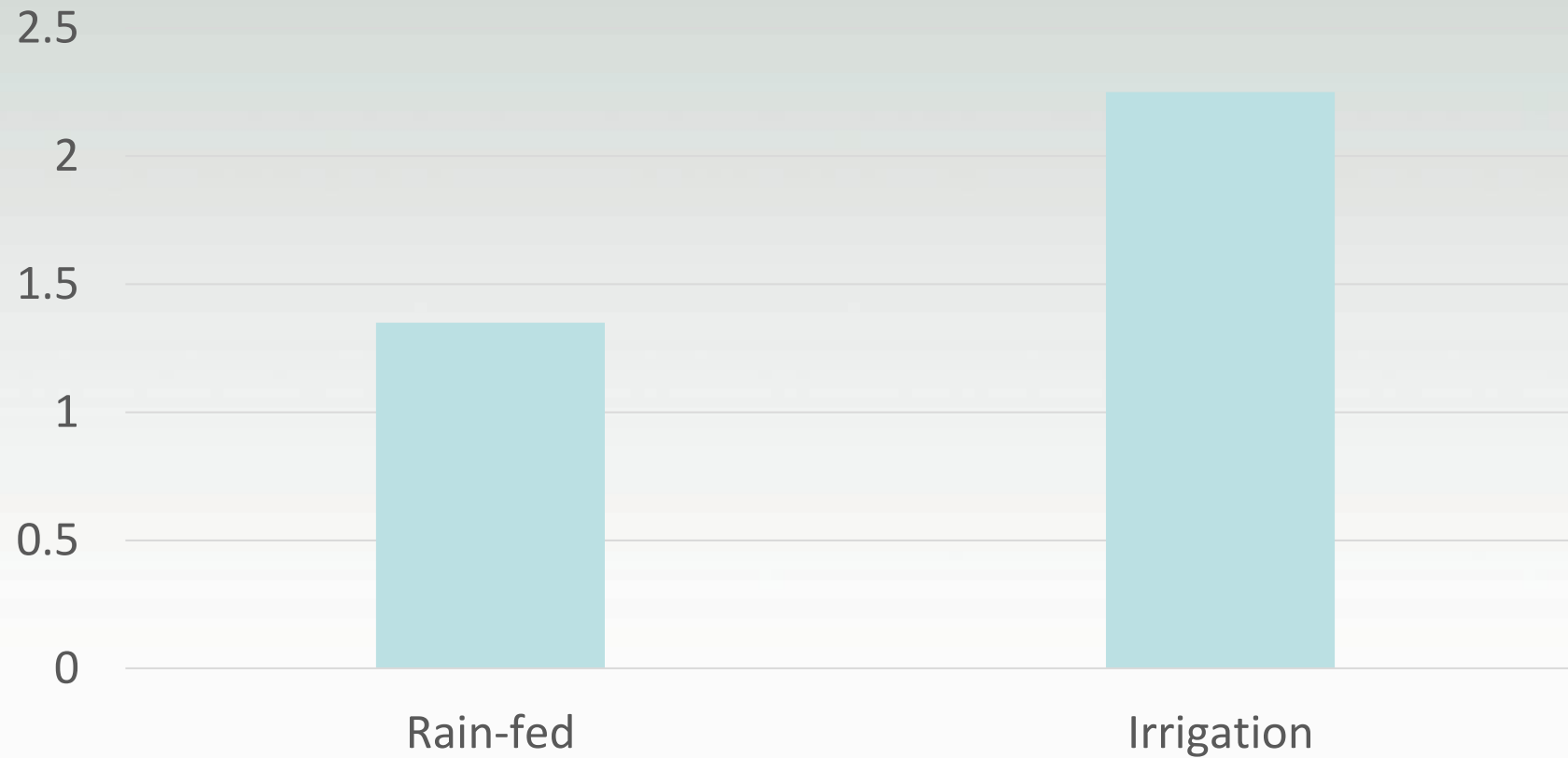
- There is a significant correlation between soil moisture and cannabinoid content. THC & CBD indicated to increase with decreasing moisture and humidity. (Latta and Eaton, 1975; Sikors et al., 2011)
- Hemp requires a plentiful supply of moisture throughout its growing season, especially during the first 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

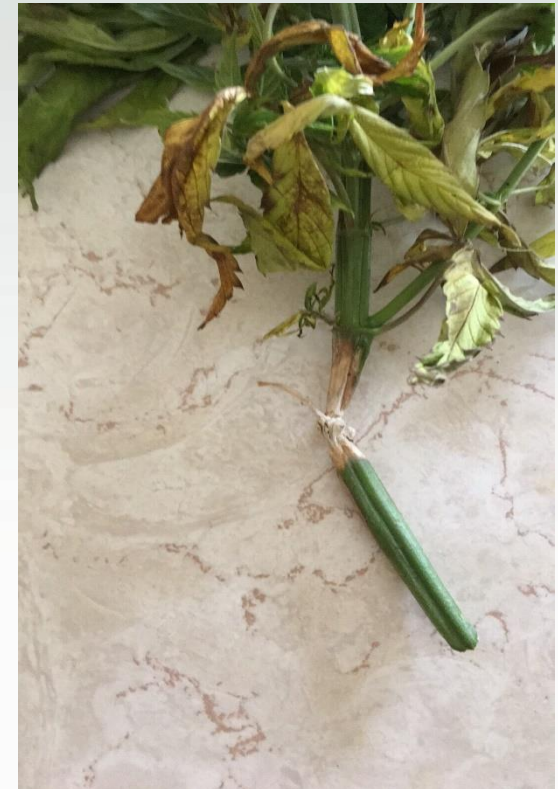


COVER CROPS



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



Products - 2019

- **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.

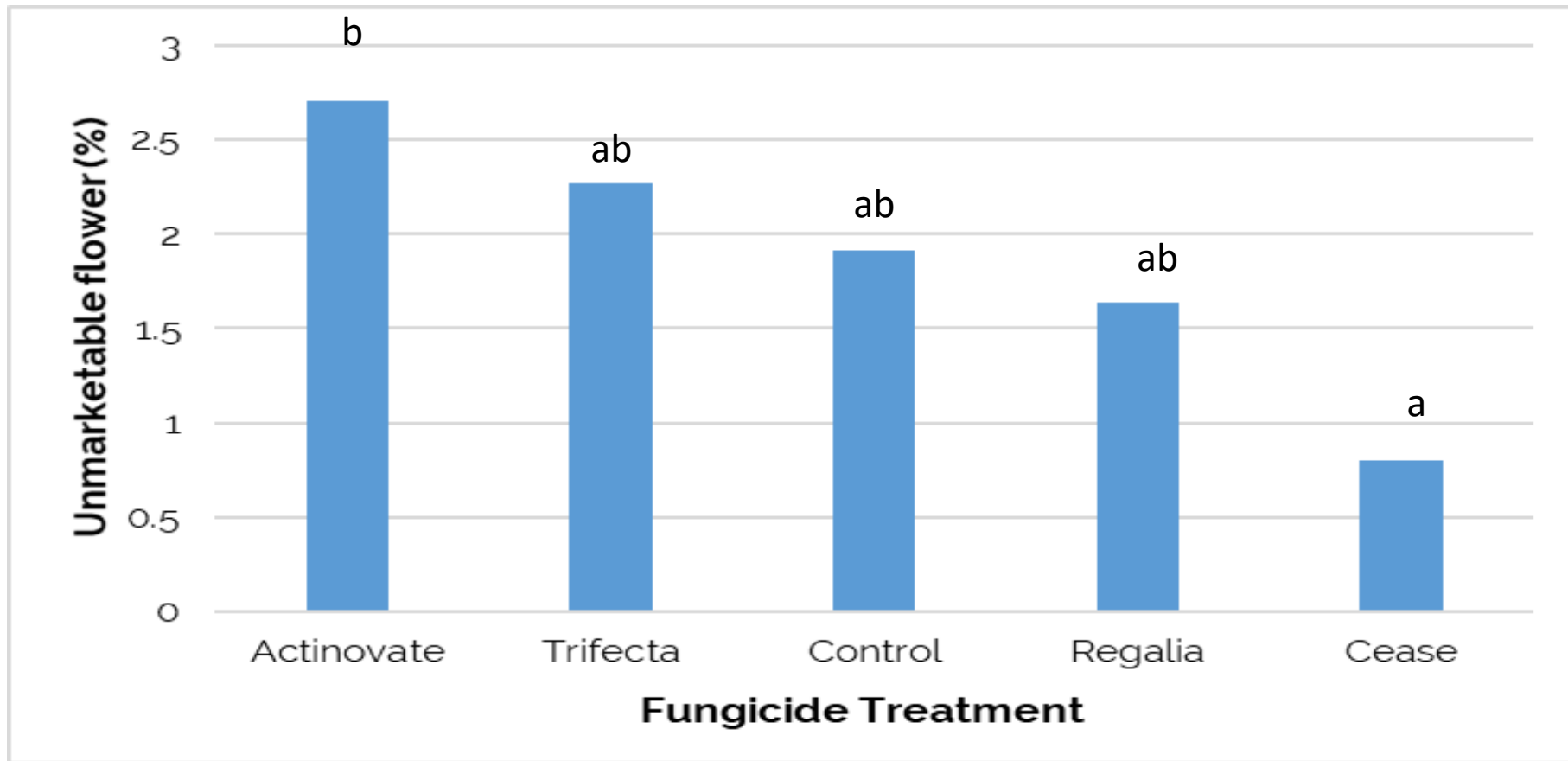


Figure 1. Unmarketable flower (%) at harvest by fungicide treatment, Alburgh, VT, 2019.

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

Treatment	Low Tunnel		Field		Overall	
	Incidence %	Shoots assessed	Incidence %	Shoots assessed	Incidence %	Shoots assessed
Kocide-3000	0.00 a	18	40.0 a	20	21.1 a	38
OxiDate	0.00 a	19	47.4 a	19	23.7 a	38
Double Nickel	10.0 a	20	36.8 a	19	23.1 a	39
Cease	5.00 a	20	35.0 a	20	20.0 a	40
Water	15.0 a	20	30.0 a	20	22.5 a	40
Overall	6.19 a	97	37.8 b	98	22.1	195



Fungicide 2021

Location	Fungicide	Copper content	Aerobic microbial count	Combined yeast and mold counts
		ppm	CFU*	CFU
Low Tunnel	Double Nickel	16.88	33,350	13,050
Field	Double Nickel	12.49	6,164	27,562
Low Tunnel	Kocide 3000	408.1	92	12,375
Field	Kocide 3000	143.0	184	5,400
Low Tunnel	Control	14.51	92	6,525
Field	Control	15.76	<LOQ†	3,600

Aerobic counts – 100,000 cfu

Yeasts/molds – 10,000 cfu

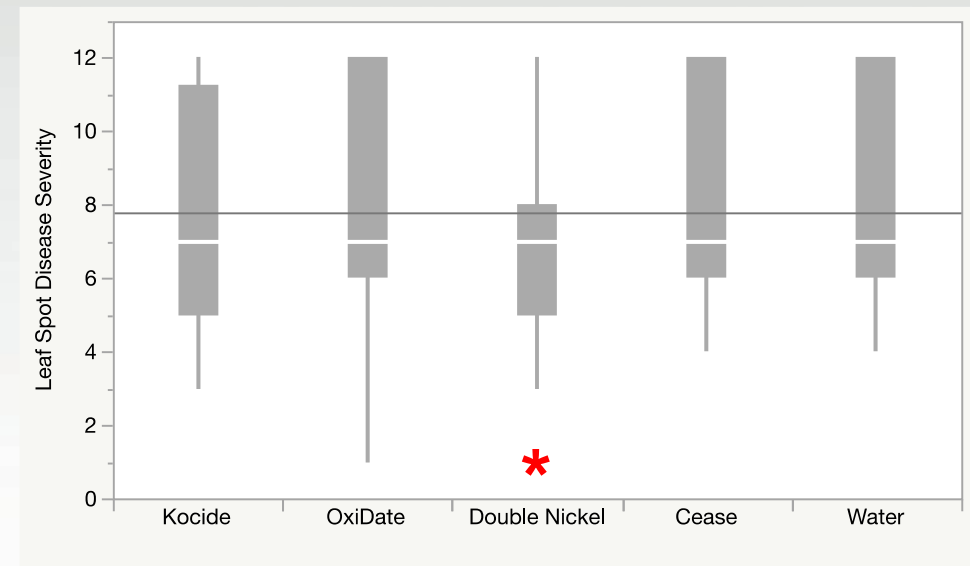


Fungicide - 2022

- 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.

	bud rot	leaf spot	powdery mildew
Cease	0.9076	0.4739	0.7161
Oxidate	0.9149	0.9038	0.7161
Kocide	0.9980	0.0602	0.9433
Double Nickel	0.5919	0.0204*	1.0000



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

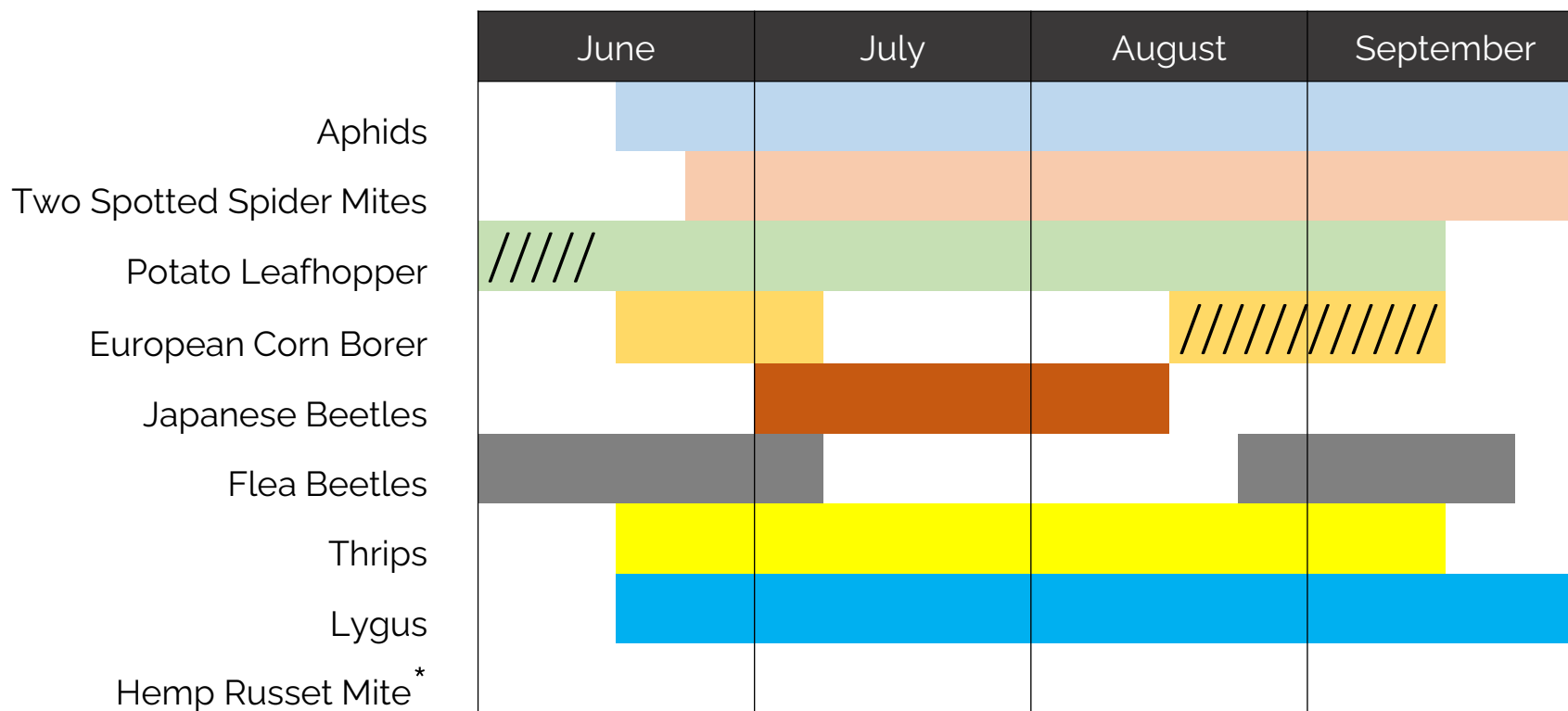
Outer root cortex slides off

Issue for seedlings and transplants

Pythium can also cause Damping Off



A Season of Pests



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



Cannabis aphid (other aphids)

Found on leaves and stems

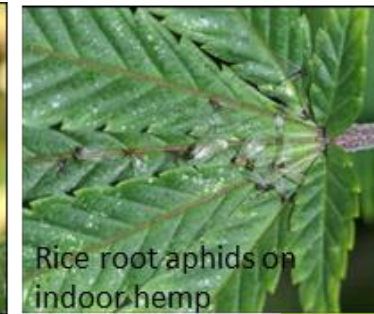
Winged and wingless forms

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



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%2ospider%2omite%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

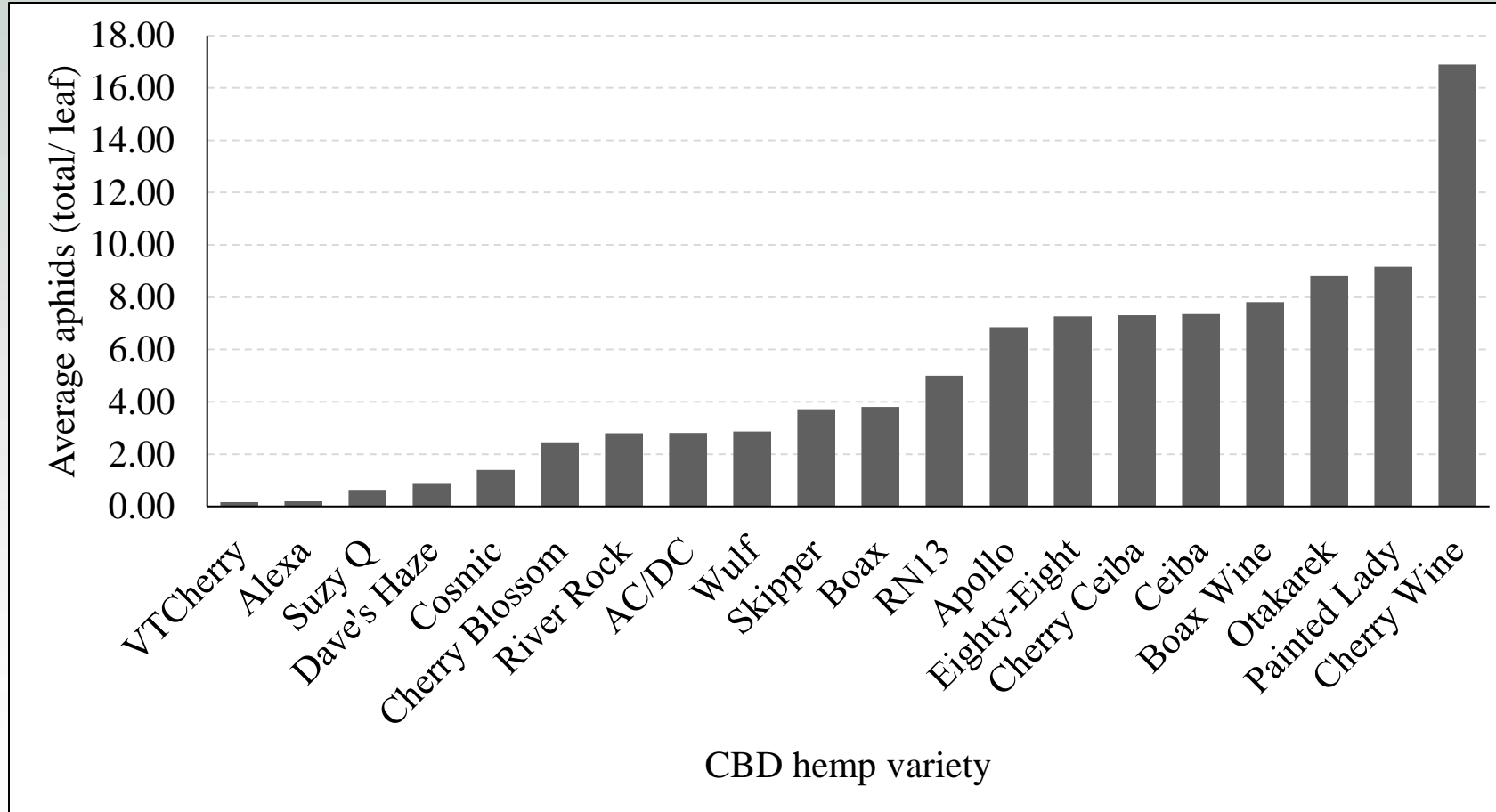
bronze/gold color. slight upward rolling may occur

Most damage on developing buds

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



CBD Variety Trial – Aphid populations



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!



That's a male



That's a female

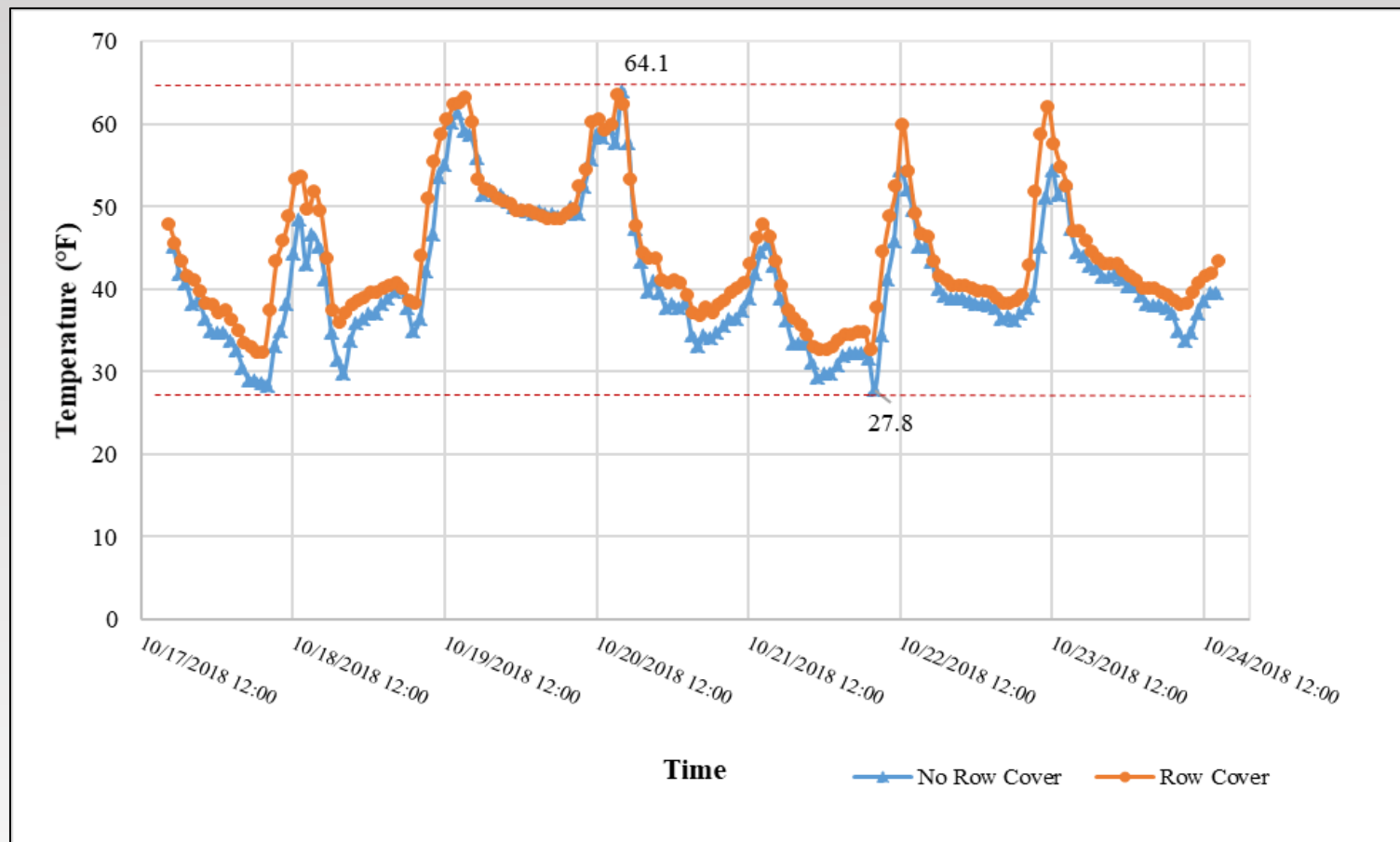


Figure 1. Average hourly temperatures at the base of the plants in row covered plots and uncovered plots.

Effect of Temperature on Potential CBD



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

Date	Total Potential Cannabidiol (%)						Temperature (°F)	
	18-Oct	19-Oct	21-Oct	22-Oct	24-Oct	26-Oct	Average	Trial average
Row cover	9.36	7.55	8.97	11.0	10.3	7.28	9.06	42.3
No row cover	9.72	9.13	6.97	11.3	10.5	8.88	9.41	39.4
LSD (0.10)	NS	NS	1.46	NS	NS	NS	NS	1.94
Trial Mean	9.54	8.34	7.97	11.1	10.4	8.08	9.23	40.9

LSD – Least significant difference.

NS – No significant difference in severity between treatments.

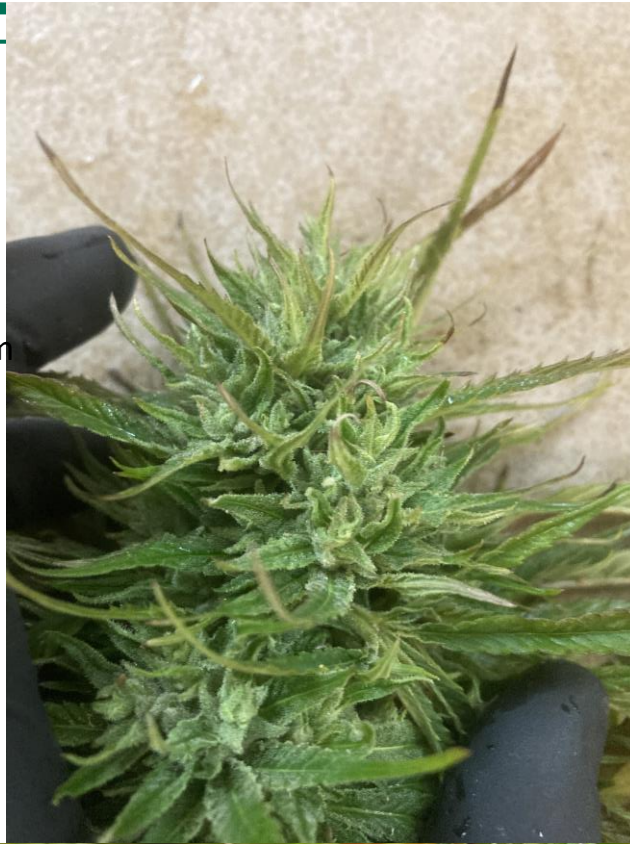
Harvest Timing



Boax
HD4



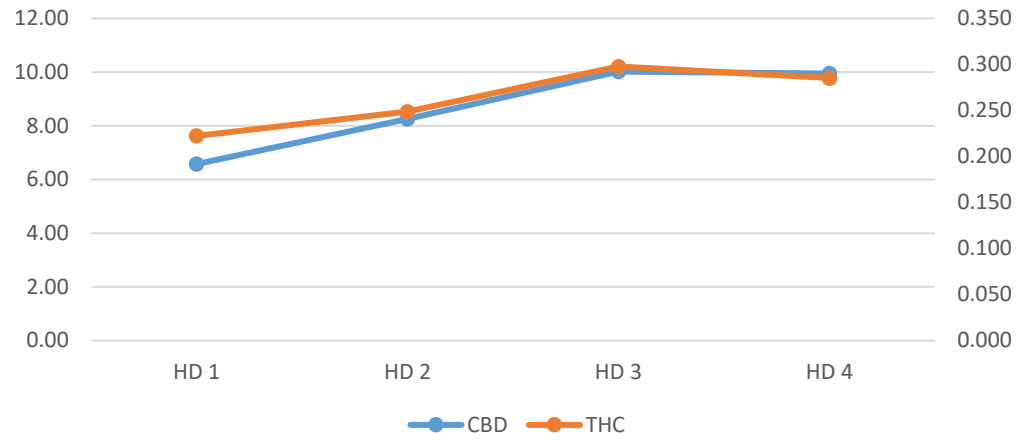
Cherry
Blossom
HD4



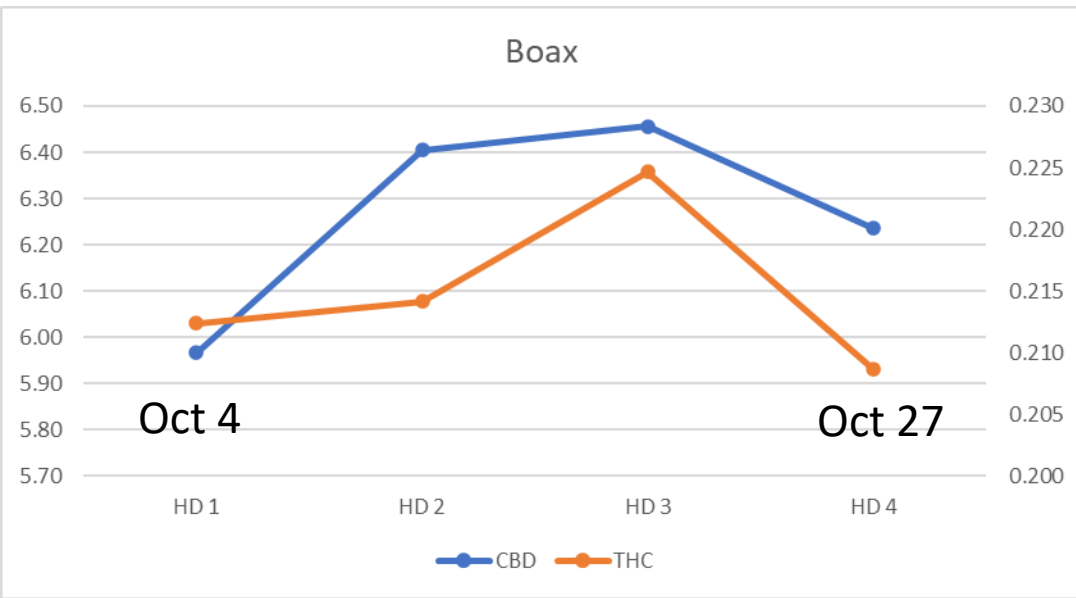
Southern
Sunset
HD4



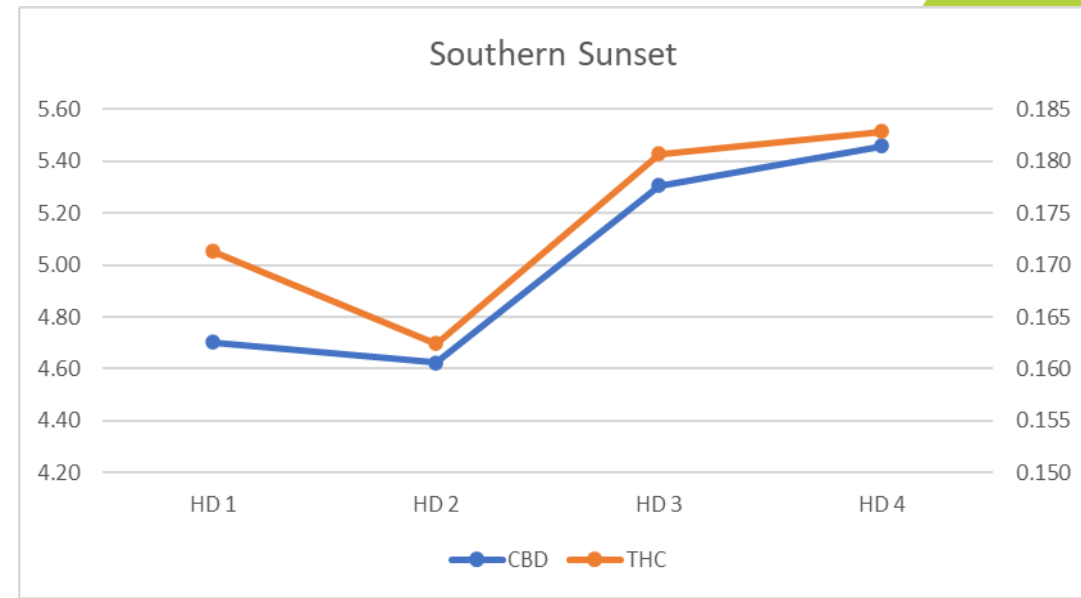
Cherry Blossom



Boax



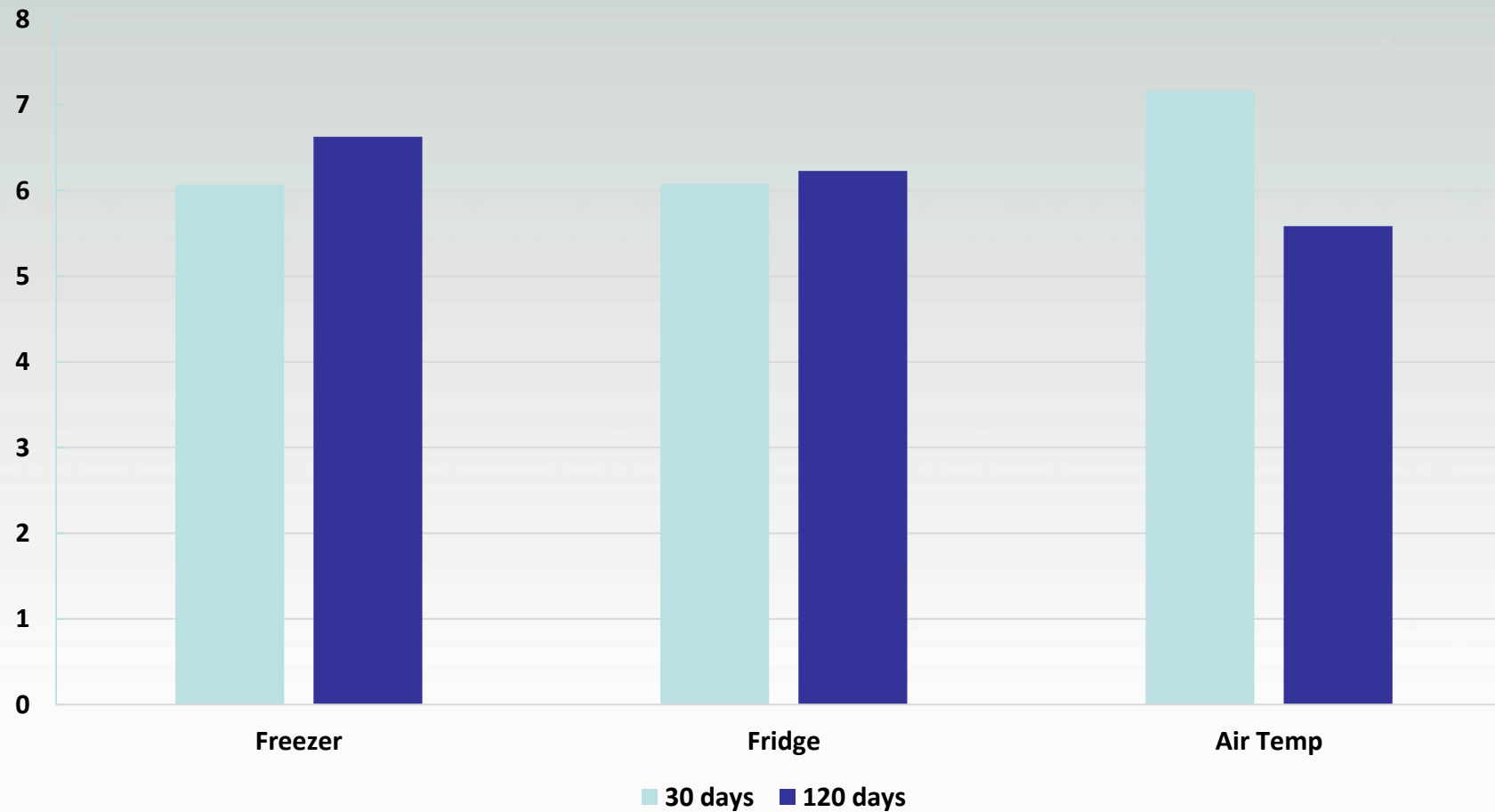
Southern Sunset



Drying Temperature

Treatment	Whole stem total potential CBD
	%
80°F	7.51
105°F	6.89
Ambient temperature	7.71
LSD (0.10)	NS
Trial Mean	7.21

Storage Temperature



Thank You

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