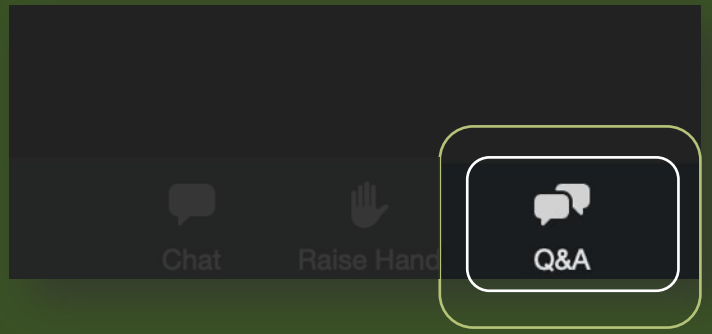

GOOD HEMP
TM
Welcome:
Session to begin shortly
Arcadia
BIOSCIENCES

Q&A icons

As seen in your Zoom webinar view



CANNABIS BREEDING PAST, PRESENT & FUTURE

WHY IT MATTERS TO HEMP GROWERS

Arcadia BIOSCIENCES

Randy Shultz, Ph.D. | Chief Technology Officer, Arcadia Biosciences

May 14, 2020

Arcadia Biosciences is focused on developing superior genetics that bring value to growers AND consumers

- Founded in 2002
- Public company in 2015 (Nasdaq: RKDA)
- Headquarters in Davis, CA

Develop the best genetics

Using advanced plant breeding and gene editing technologies

Optimizing crops to improve health benefits, quality and productivity

Bring valuable ingredients to consumers

Ardent Mills

CORTEVA™ agriscience

BIOCERES

Accelerating innovation through partnerships with industry leaders

Developing specialty ingredients with advanced nutritional profiles

Current hemp industry lacks maturity and professionalism demanded by large-scale farmers

2014 & 2018
Farm Bills legalized hemp leading to a boom in the industry

2019 (10/31)
USDA-AMS published IFR regulations for domestic hemp program

2020
States refine rules to comply with USDA

Lack of FDA action holding back full industry expansion

Industry challenges

- Misinformation, farmer education
- Some bad actors
- Limited agronomic data
- Shifting regulatory environment
- Lack of good genetics
- Market access for harvest
- Immature supply chain

Pain points for growers

- Poor quality of seeds/clones
- Non-compliant THC (destruction)
- Weed, pest and pollen control
- Chemotype “off types”
- High labor “gardening”
- Lack of crop uniformity
- Genetics not regionally adapted

Brief introduction to *Cannabis sativa*

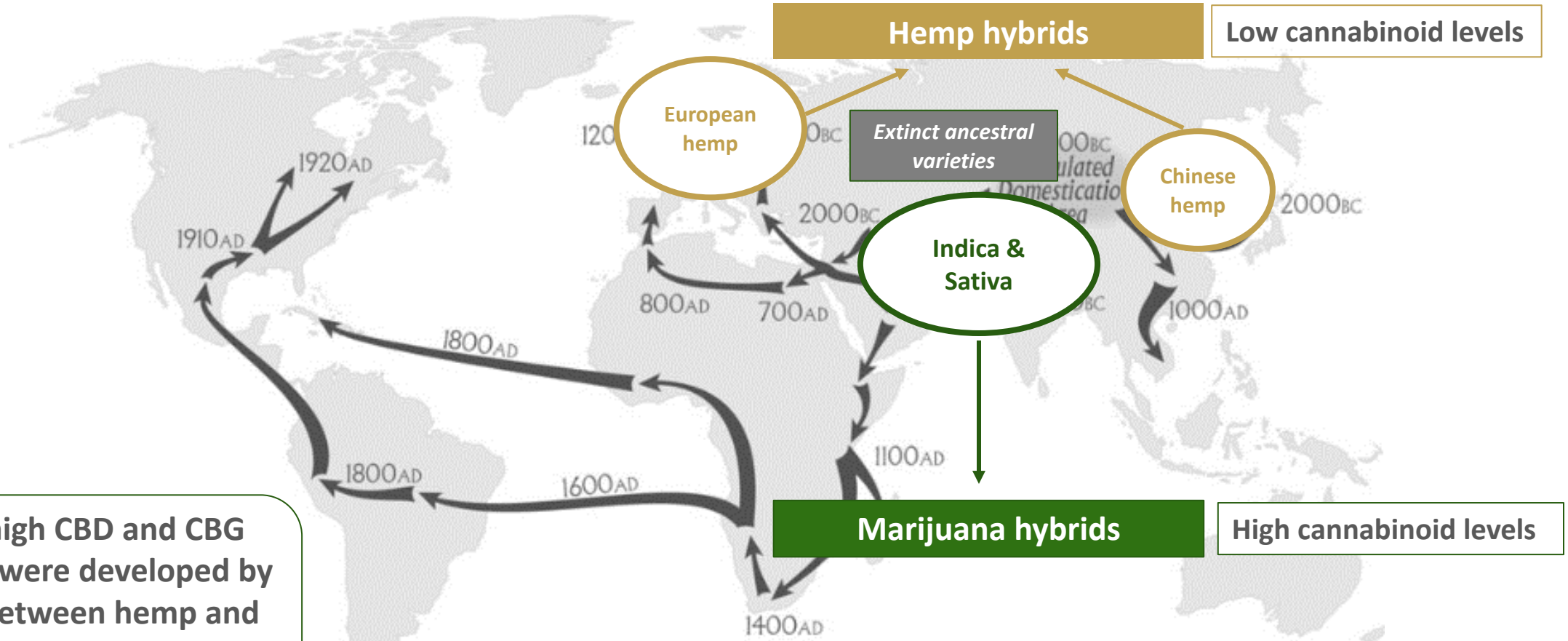
Courtesy of CU Museum of Natural History

Characteristics **(and grower challenges)**

- Annual, fast growing
- Short day induces flowering (mostly)
- Seed contains high quality protein & oil
- Biomass has many industrial uses
- Relatively low-maintenance to produce
- Dioecious (separate male & female plants)
- XY sex chromosomes
- Obligate out-crosser
- Wind pollinated (light, robust pollen) **– inadvertent pollination**
- Secondary metabolite factory (THC, CBD, terpenes) **– compliance**
- Stress can induce hermaphrodites **– reduced yield**
- Semi-domesticated **– reduced yield**

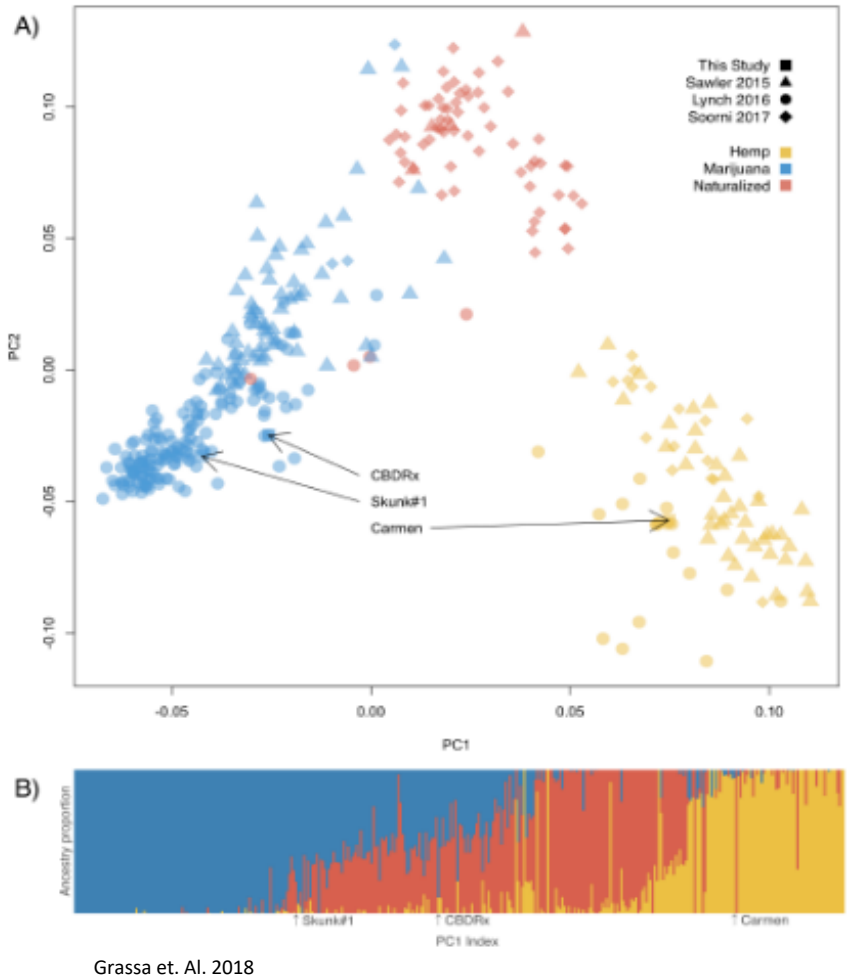
Hemp = Cannabis with <0.3% THC

Cannabis is thought to have first been domesticated in the Himalayan foothills over 10,000 years ago



Current high CBD and CBG varieties were developed by crosses between hemp and marijuana varieties

Genomic analyses show that current high CBD varieties are mostly marijuana-type genetics

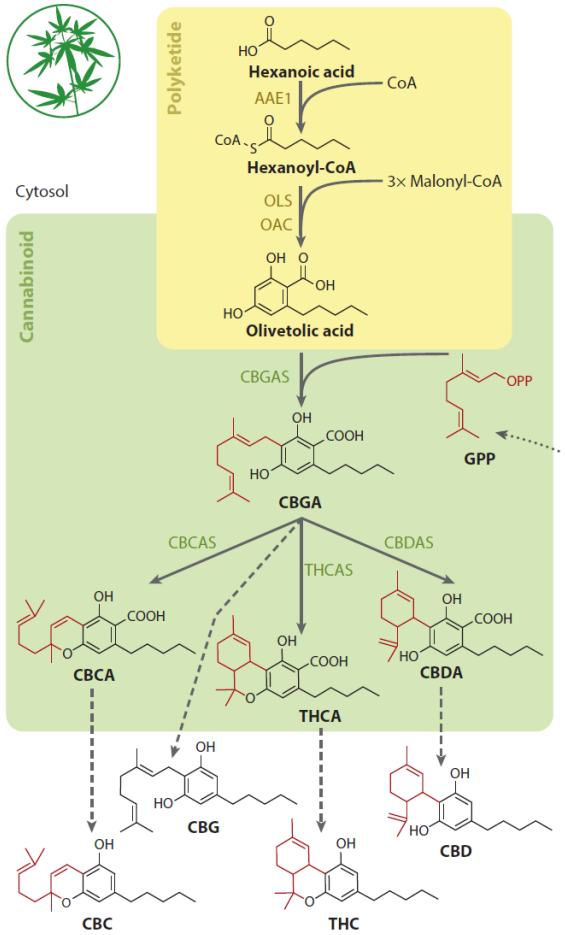


Grassa et. Al. 2018

- Blue cluster is marijuana type cannabis
- Yellow cluster is industrial hemp
- Red cluster is naturalized (feral) cannabis
- Today's high CBD lines clearly cluster with the blue
- However THC has been reduced by breeding in the hemp-type CBD and THC synthesis genes
- This means that high CBD lines have not been optimally bred for broad acre agriculture or regional adaptation

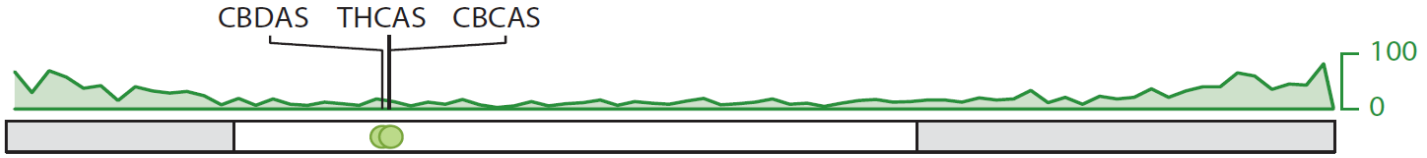
There is a huge opportunity to use modern breeding technology to rapidly improve this crop!!

Hemp vs marijuana alleles of CBD and THC synthesis genes determine the varieties chemotype



Chemotypes are **chem**ical phen**otypes**

- The 4 chemotypes result from different combinations of genes involved in the cannabinoid synthesis pathway
- CBGA is the precursor of both THC and CBD



- Type I: THC>>CBD due to inactive CBDAS gene
- Type II: THC~=CBD both are functional genes
- Type III: CBD>>THC due to inactive THCAS gene
- Type IV: CBG builds up because all are inactive

Hemp growers must grow Type III or IV – otherwise not compliant!

Grower watch-out: many “reputable” seed providers deliver seed segregating off-types

Variety	Total	Type III	Type II	Type 1	% off-type
Arcadia ASG202-1001	846	838	8	0	< 1%
Competitor variety#1	111	102	9	0	8%
Competitor variety#2	505	353	138	14	30%
Competitor variety#3	137	137	0	0	0%
Competitor variety#4	98	67	26	5	32%

Data generated with GC-FID protocols

We use metabolite analysis to ensure type purity and to drive breeding of improved varieties

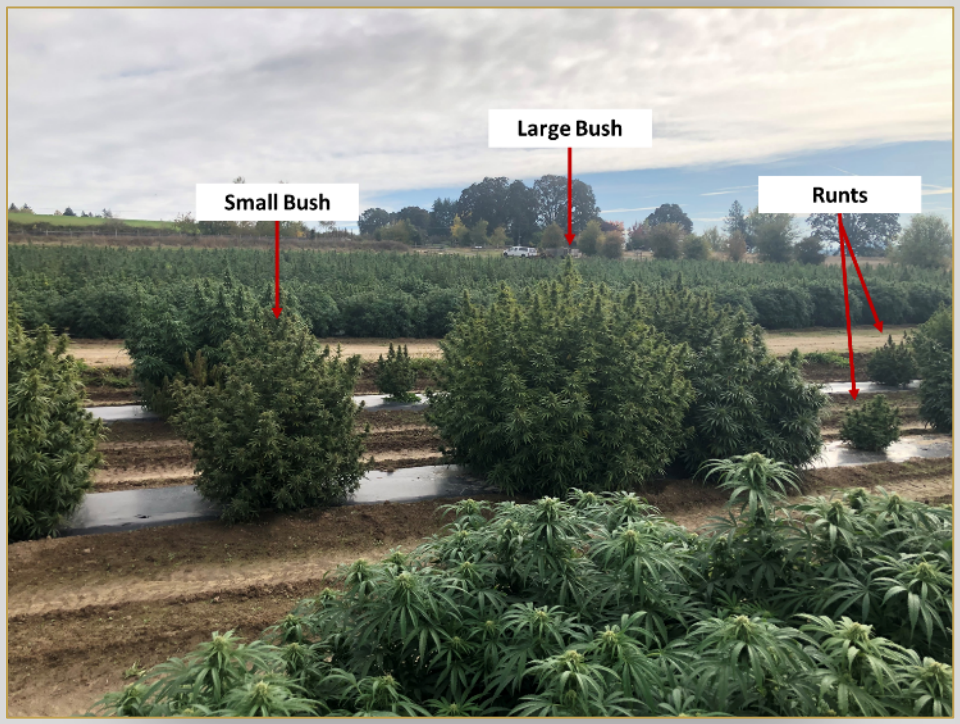
In house chromatography

- Measure cannabinoid and terpene profiles
- Purge off-types in all seed production runs
- Quality control in seed production
- Use chemotype data in breeding selections
- Weekly monitoring to determine harvest time

							µg/mg (mg/g)									
Planting Date	Sample date	PIMS #	Variety	Sample (mg)	Estimated DW (mg)	Leaf or Flower	CBDV	THCV	CBC	CBD	delta-8-THC	THC	CBG	CBN	THC/CBD ratio	Chemotype
8/29/2019	9/19/2019	10008352626	BaOx	86.8	21.7	L	0.011	0.015	0.609	**0.901**	0.008	**0.031**	0.152	0.026	29	III
8/29/2019	9/19/2019	10008352619	BaOx	73.5	18.375	L	0.000	0.017	0.480	**0.535**	0.000	**0.020**	0.013	0.029	27	III
					0											
8/29/2019	9/19/2019	10008351757	Berry Wine	112.1	28.025	L	0.040	0.268	1.232	**0.333**	0.000	**0.356**	0.086	0.039	0.9	II
8/29/2019	9/24/2019	10008351757	Berry Wine	155.7	38.925	L	0.174	0.164	1.073	**0.086**	0.006	**0.212**	0.013	0.019	0.4	II
8/29/2019	9/19/2019	10008351788	Berry Wine	86.3	21.575	L	0.000	0.008	0.194	**0.636**	0.006	**0.029**	0.020	0.026	22	III
					0											
8/29/2019	9/19/2019	10008352172	Casino Cookies	84.9	21.225	L	0.000	0.037	0.871	**0.608**	0.000	**0.031**	0.010	0.022	20	III
8/29/2019	9/19/2019	10008352186	Casino Cookies	107.5	26.875	L	0.000	0.019	1.388	**0.219**	0.000	**0.126**	0.014	0.016	1.7	II
8/29/2019	9/24/2019	10008352186	Casino Cookies	144.3	36.075	L	0.027	0.027	1.228	**0.344**	0.028	**0.190**	0.026	0.015	1.8	II
8/29/2019	9/19/2019	10008352193	Casino Cookies	114.2	28.55	L	0.000	0.010	0.850	**0.401**	0.005	**0.020**	0.007	0.018	20	III
8/29/2019	9/19/2019	10008352206	Casino Cookies	126.5	31.625	L	0.006	0.011	1.004	**0.727**	0.010	**0.032**	0.014	0.022	23	III
8/29/2019	9/19/2019	10008352129	Casino Cookies	98.6	24.65	L	0.000	0.040	0.675	**0.314**	0.000	**0.156**	0.010	0.020	2.0	II
8/29/2019	9/24/2019	10008352129	Casino Cookies	141.9	35.475	L	0.000	0.007	0.389	**0.381**	0.000	**0.204**	0.023	0.019	1.9	II
8/29/2019	9/19/2019	10008352117	Casino Cookies	113.9	28.475	L	0.000	0.034	0.518	**0.818**	0.009	**0.037**	0.020	0.022	22	III
8/29/2019	9/19/2019	10008352140	Casino Cookies	107.2	26.8	L	0.000	0.028	0.431	**0.414**	0.000	**0.017**	0.008	0.019	24	III
8/29/2019	9/19/2019	10008352138	Casino Cookies	90.5	22.625	L	0.000	0.031	0.906	**0.299**	0.000	**0.014**	0.017	0.021	21	III
8/29/2019	9/19/2019	10008352164	Casino Cookies	105.1	26.275	L	0.000	0.019	0.391	**0.102**	0.009	**0.188**	0.007	0.021	0.5	II
8/29/2019	9/24/2019	10008352164	Casino Cookies	115.9	28.975	L	0.014	0.023	0.256	**0.129**	0.052	**0.265**	0.040	0.017	0.5	II
8/29/2019	9/19/2019	10008352155	Casino Cookies	118.6	29.65	L	0.006	0.011	0.458	**0.532**	0.005	**0.025**	0.016	0.023	21	III
					0											

Grower watch-out: uniformity is lacking in many currently available varieties

Variation in purchased commercial seed



Uniformity in one of Arcadia's varieties

Grower watch-out: disease problems in popular varieties illustrates the need for regionally adapted lines

Hemp: One species, three distinct market classes

1 Wellness: cannabinoids, essential oils

Production practices and challenges

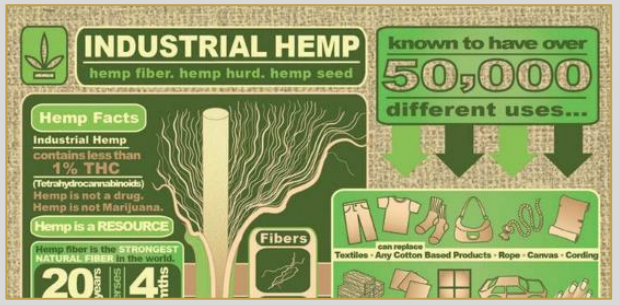
- Lower density planting, specialty crop model
- Quality, consistency, traceability
- Designer/custom cannabinoid profiles
- High touch // high value
- THC compliance

2 Plant protein

Production practices and challenges

- High density planting, row crop model
- Yield and harvest index
- Meet industry quality standards
- Dual use crops (grain + fiber)
- Lower margins per acre
- Lack of processing infrastructure

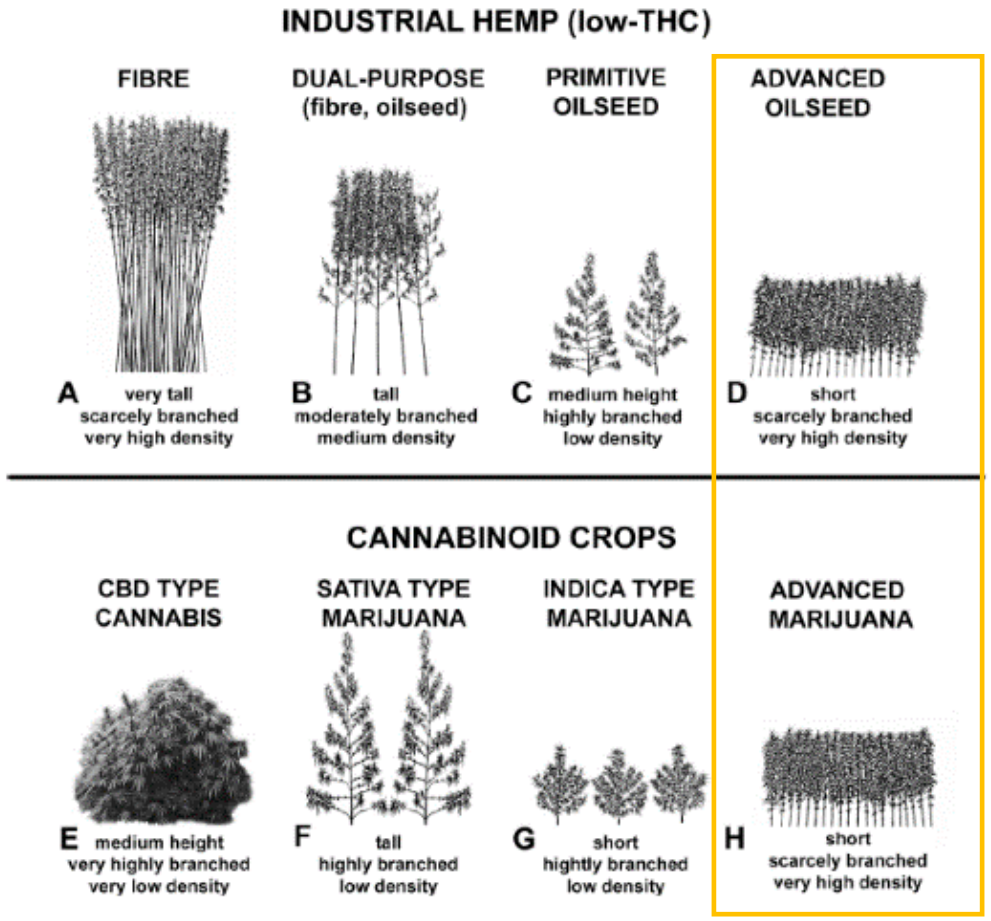
3 Fiber and industrial use



Arcadia's R&D platform accelerates key bottlenecks in a traditional breeding program: enables rapid crop improvement

Key bottlenecks in hemp breeding

1. Define market class & ideotype
2. **Assemble diverse germplasm**
3. Develop breeding plan
4. Make crosses (determine combining ability)
5. **Phenotype & regional trialing**
6. **Make selections (accelerate with genomics)**
7. **Introduce valuable traits (yield, disease, etc.)**
8. Stabilize parental lines
9. Commercialize hybrids



Earnest Small

ArcaTech platform enables rapid non-GM development and commercialization of elite hemp varieties

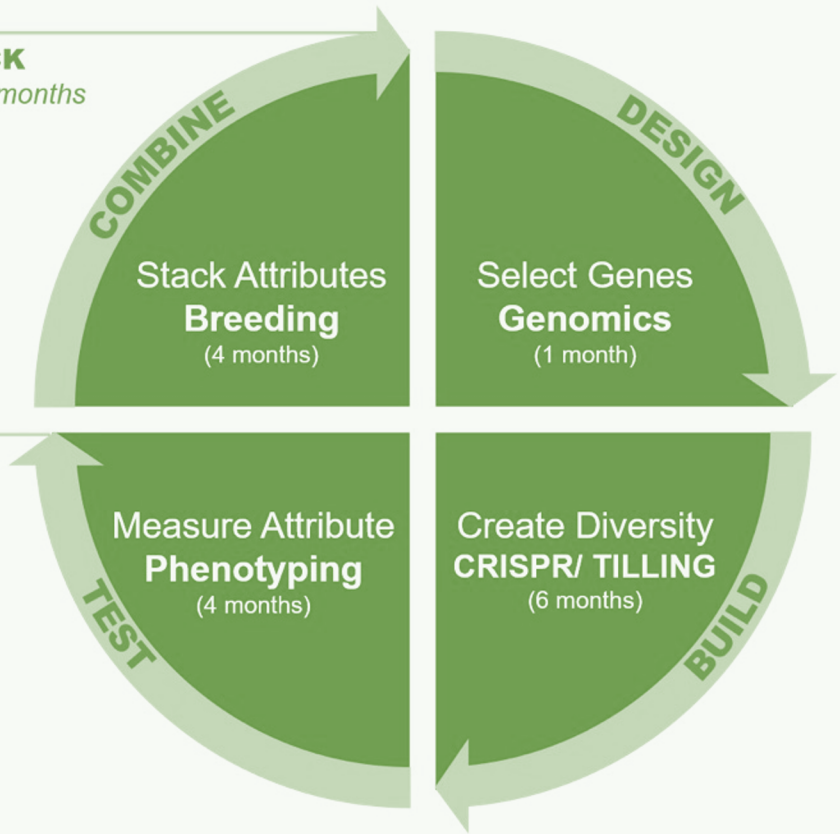
ARCATECH

Custom Designed Varieties

- THC Free
- Disease Resistant
- Double Yield
- Pollen Proof
- Herbicide Tolerant
- Custom Cannabinoids
- Increase Protein Content

DEPLOY STACK
Stacking adds 4 months

DEPLOY ATTRIBUTES
11-month cycle from concept to commercial handoff



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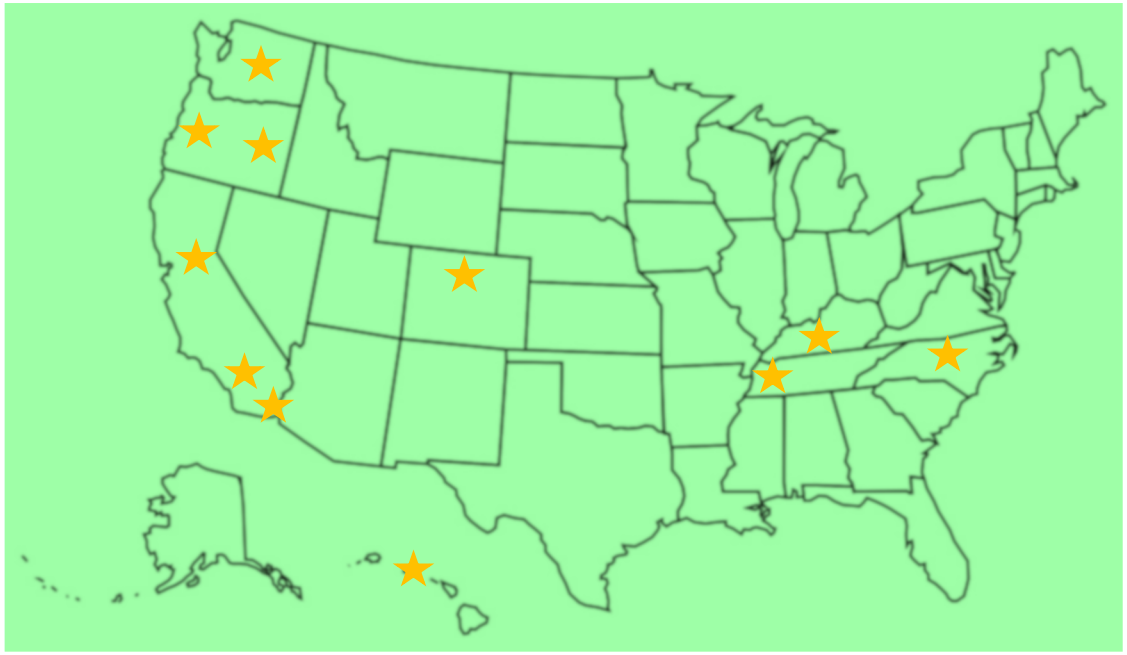
Multi-state regional testing accelerates variety adaptation and yield improvement

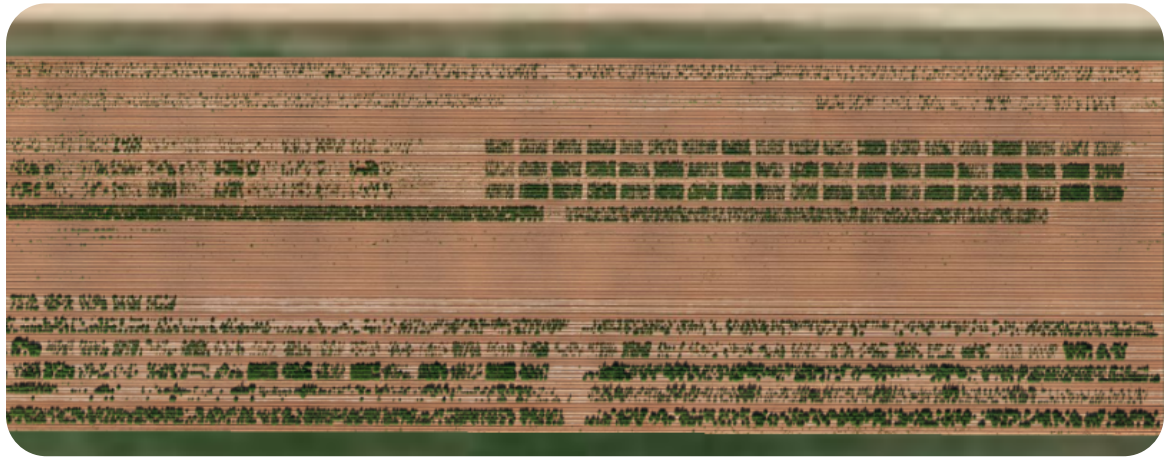
ARCATECH



★ Arcadia research or collaborator location

- Commercial and pre-commercial variety evaluation across different environments
- Early stage R&D trialing
- Breeding selection fields

Aerial photo from our IV winter trials (April 2020)

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THANK YOU
Please join for our next session:
“Feminized Seeds: Be A Good Neighbor & Improve Profits”
Thursday, May 28th, 10 am pacific time | 1 pm eastern time
www.GrowGoodHemp.com
www.HempInnovationSeries.com