Current Status of Non-Fumigant Technologies

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Why the need?

Alternative fumigants are less broad-spectrum and more target-specific and a combination with other fumigants or pesticides is often required to reach the level of pest control efficacy and yield response as methyl bromide.

Chemicals such as 1,3-D and Pic are heavily regulated.

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Why the need?

1,3-Dichloropropene (Telone):

- California: 1,3-D use is limited to 136,000 lbs per township (36 sq. miles).
- No rollover, year to year.
- December ban.

Health risk. Potential carcinogen.

- In Virginia and much of the mid-Atlantic, surface water, and high water tables, and the close proximity of crop production areas to environmentally sensitive estuaries makes the use of 1,3-D limited.

Why the need?

Chloropicrin (Pic)

Restrictions on the use of product near sensitive sites near schools, day care centers, and hospitals.

If fumigation block is within ¼ mile of sensitive sites

- A maximum of 10 acres per 24 hours may be treated.
- Injection must be completed 36 hours prior to the start of a school session.

Health risk. Lung, skin, eye irritant.

Why the need?

Given these regulations and resistance from public to use of fumigants, there is a need to evaluate and find non-fumigant alternatives to methyl bromide fumigation.

Herbicide options limited as compared to other row crops. No new chemistries.

Soil Solarization

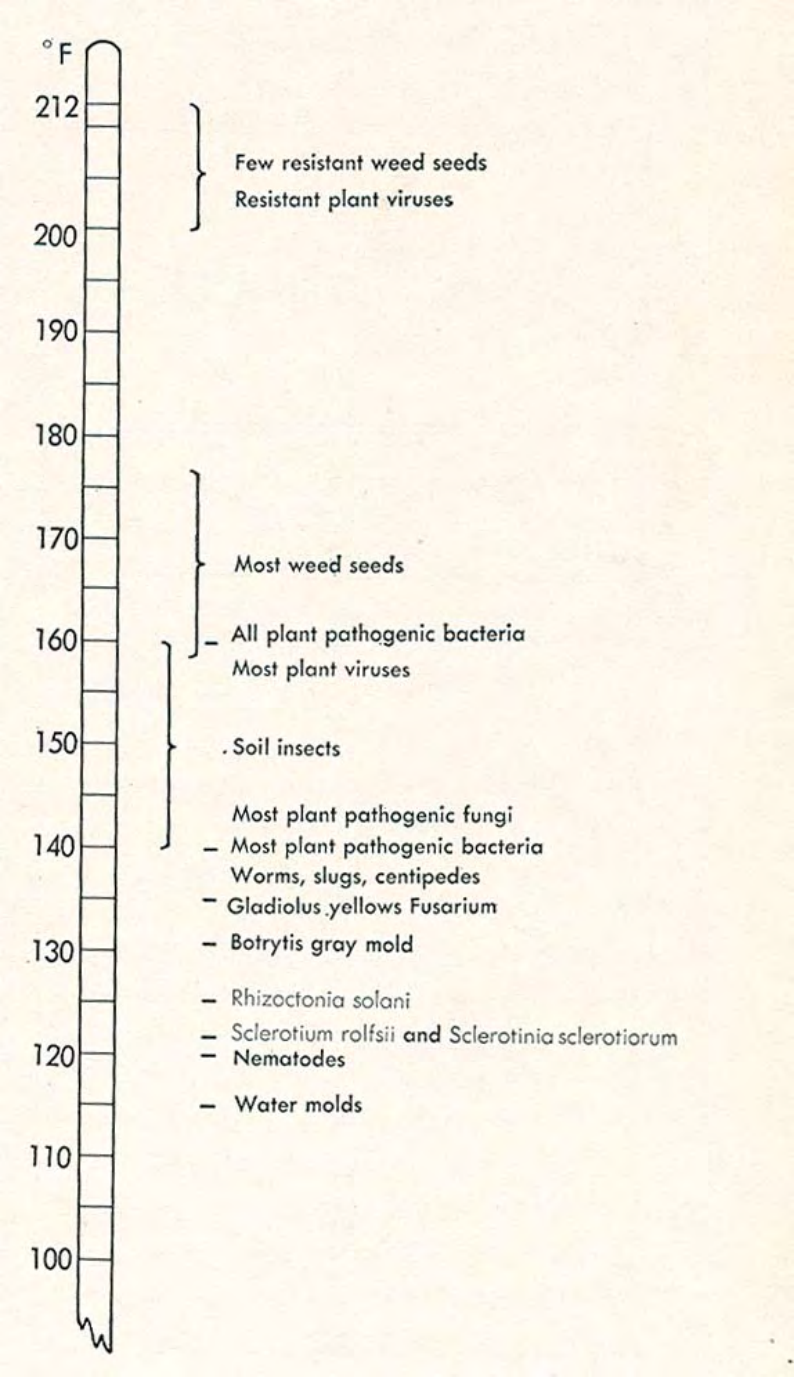
- Israel, Japan, and USA.

- Earlier studies in the U.S., *Verticillium wilt* in solanaceous crops and cotton.

- Achieved by using a clear polyethylene tarp during the summer season.

- Traps heat which increases the soil temperature.

Figure 3. Application of transparent polyethylene film to solarize a field on an organic vegetable farm in the San Joaquin Valley, California. (Source: University of California)



Constant temperature of 35 °C (95 °F) for 45 d reduced *V. dahliae* microsclerotia by 70%.

Linear relationship between time and temperature exposure duration.

Steaming recommendation 70 °C 158 °F for 20 min. period.

Soil solarization accrual > 40 °C (104 °F).

K.F. Baker, 1957

Factors influencing soil solarization

- Bed orientation (preferably N/S orientation)
- Plastic film thickness and color
- Soil water content (at least 70% field capacity)
- No air pockets
- Good contact between the soil and the tarp
- Weather

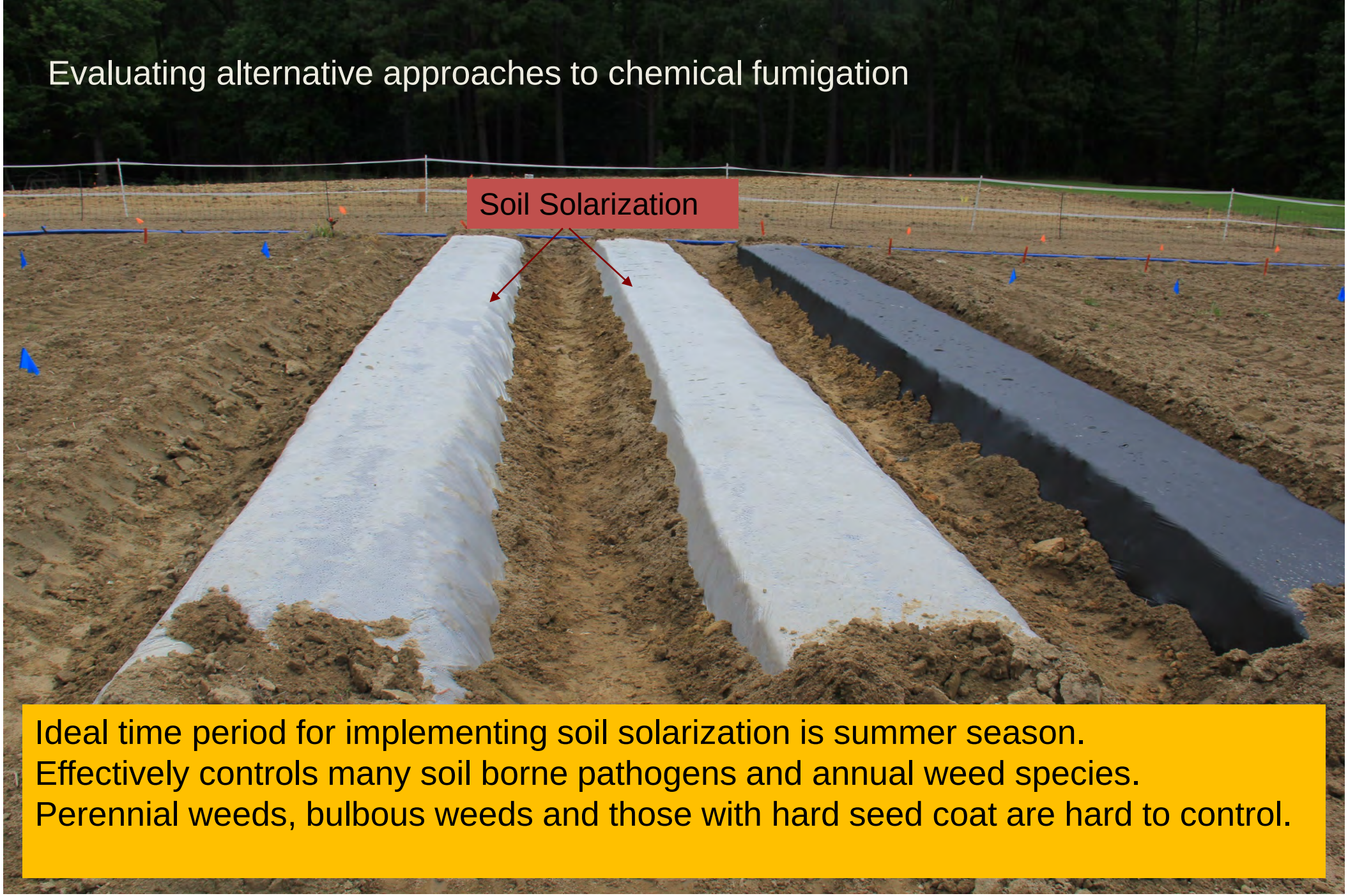
Soil Solarization

- Controls root diseases caused by *Phytophthora spp.* in strawberry and raspberry (Pinkerton et al., 2002).

Challenges

- Border effect
- Long duration: minimum 4 to 6 week period.

Evaluating alternative approaches to chemical fumigation



Ideal time period for implementing soil solarization is summer season.
Effectively controls many soil borne pathogens and annual weed species.
Perennial weeds, bulbous weeds and those with hard seed coat are hard to control.

- Over both seasons, the 6 wk SS treatment consistently lowered the weed density compared to the nontreated control.
- Weed density in the 6 wk SS treatment was not statistically different from the 4 wk SS treatments in the 2013-14 growing season.
- In both seasons, crop yield in the 4 wk SS was significantly lower than other treatments.

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Samtani et al., Weed Technology 2017 31:455–463

Mustard Seed Meal

-Mustard seed meal (MSM), a by-product of the mustard oil extraction process.

- Brassicaceae family plants possess allelopathic properties to inhibit weed germination, emergence, and growth (Rice et al., 2007).

- Toxic to nematodes and soil-borne pathogens.

- Allelopathy is due to sulfur-containing glucosinolates.

Mustard Seed Meal

- Efficacy is enhanced with warm temperatures, neutral pH, and dilution with water.

- Meal from *Sinapsis alba* more efficacious than *B. juncea* or canola (B. napus L.)

- Biofumigation increased bacterial diversity and fungal diversity was decreased and it increased total soil N, available P and K (Ntalli and Caboni, 2017; Wang et al., 2014).

$1.28/lb.

Mustard Seed Meal, Challenges.

- Weed control is limited to early season.
- Efficacy of mustard seed meal can be inconsistent across years. Higher rates are needed for effective pest control.
- Product must be applied a few days before transplanting (2 to 3 weeks lead time).
- Treatment is expensive.
- Limited product choice in the market.

Enhanced Soil Solarization

- Efficacy of SS can be improved by addition of
pesticides, organic fertilizers and biological agents, particularly in cooler areas.

Examples.

- SS and *Trichoderma* treatment reduced *P. cactorum,* increased yields.

- Chicken litter with SS reduced diseases of sweet potato and controlled
southern root-knot nematode and increased lettuce yield for two years.

CGM

PM

MSM

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Trifolium repens L. (white clover)

Stellaria media (L.) Vill. (common chickweed)

Gnaphalium L. (cudweed)

Coronopus Zinn (swinecress)

Allium vineale L. (wild garlic)

Oxalis L. (woodsorrel)

S. Das, Ph.D.

Cumulative total weed density (5 ft. window): 2013-2014 growing season at Southern Piedmont AREC

Treatment	Tarp	Total Weed Density	Letter Group
Untreated Control	Black	185.0	A
Solarization 4wk PP	Clear	169.0	AB
Pic-Clor 60 @ 140 lbs/A shank applied	Black	111.3	BC
Solarization 4 wk + Mustard Seed Meal PP	Clear	103.8	CD
MSM 8 wk PP	Black	64.5	CDE
Solarization 8wk PP	Clear	56.5	CDE
MSM 4wk PP	Black	48.5	DE
Solarization 8 wk PP + MSM	Clear	37.5	E

Pr > F = 0.0003

Cumulative total weed density (5 linear ft. window) :2014-2015 growing season at Southern Piedmont AREC, Blackstone, VA.

Treatment	Tarp	Total Weed Density	Letter Group
Solarization 4wk PP	Clear	134.0	A
Untreated Control	Black	130.5	A
Solarization 4wk PP+ Mustard Seed Meal (1000 lb/A)	Clear	111.2	AB
MSM 4wk PP	Black	86.2	BC
MSM 8wk PP	Black	60.2	CD
Solarization 8wk PP	Clear	49.2	DE
Pic-Clor 60 @ 140 lbs/A shank applied	Black	44.7	DE
Solarization 8wk PP + MSM	Clear	24.7	E

Pr > F <0.0001

Total Marketable Yield for Southern Piedmont AREC in 2014-15 growing season, Southern Piedmont AREC, Blackstone, VA.

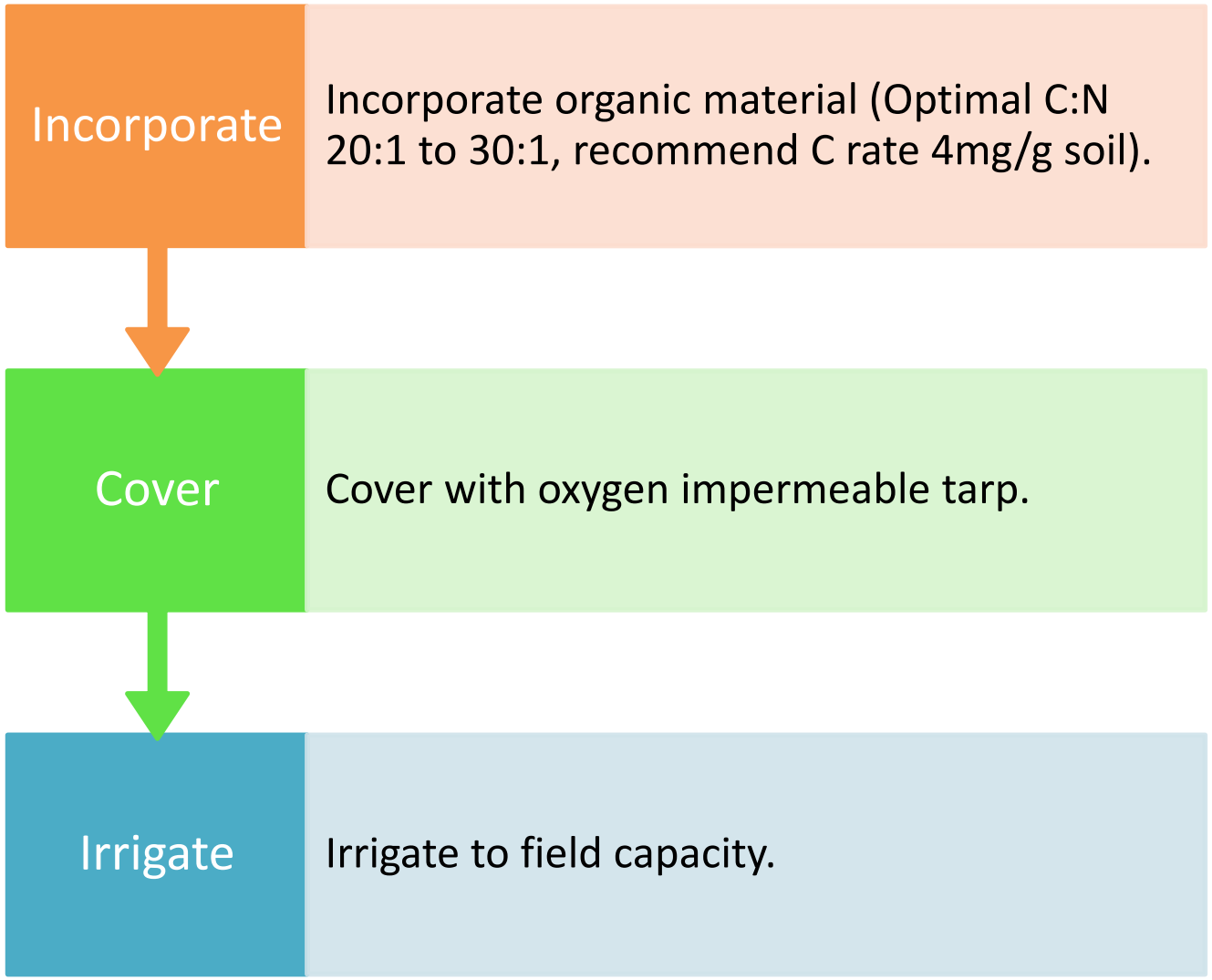
Treatment	Yield (lb/plant)	Letter Group
Pic Clor 60	1.1	A
Solarization 8wk + MSM (1000 lbs/A)	0.8	AB
Solarization 8wk	0.8	AB
MSM 8wk PP	0.8	BC
MSM 4wk PP	0.8	BC
Untreated Control	0.7	BC
Solarization 4wk PP + MSM	0.6	C
Solarization 4wk PP	0.6	C

Pr > F 0.0071

Anaerobic Soil Disinfestation

- ASD, known also as Biological Soil Disinfestation (BSD) or as Reductive Soil Disinfestation (RSD)
- Developed as an alternative to other soil chemical fumigants independently in Japan and in The Netherlands
- ASD is considered one of the most promising **non-chemical** methods for pest control.

ASD 3-Steps


Incorporate
Incorporate organic material (Optimal C:N 20:1 to 30:1, recommend C rate 4mg/g soil).
Cover
Cover with oxygen impermeable tarp.
Irrigate
Irrigate to field capacity.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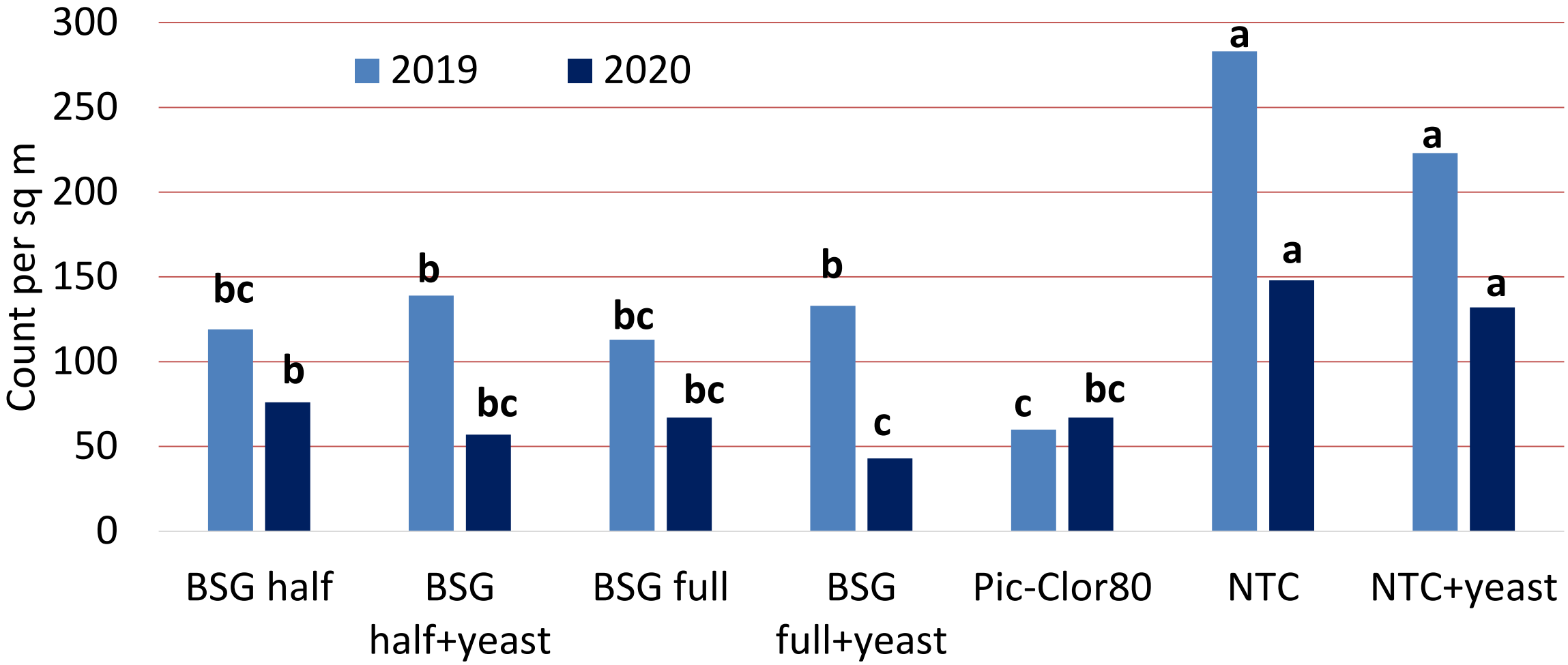
New Research

- Evaluate the effect of **carbon sources with yeast** in ASD treatments in field condition.
- Evaluate the ASD with **reduced carbon rates** in field condition with tested C source.

Weed species observed in study:

Shepherd`s Purse (*Capsella bursa-pastoris*)	Bermuda (*Cynodon dactylon*)	Crabgrass (*Digitaria sanguinalis*)
Carpetweed (*Mollugo verticillata*)	Yellow Nutsedge (*Cyperus esculentus*)	Wild Garlic (*Allium ursinum*)
Henbit (*Lamium amplexicaule*)	Common Purslane (*Portulaca oleracea*)	Carolina Geranium (*Geranium carolinianum*)
White Clover (*Trifolium repens*)	Cudweed (*Gnaphalium spp.*)	Common knotweed (*Polygonum arenastrum*)

Cumulative weed count (all species)



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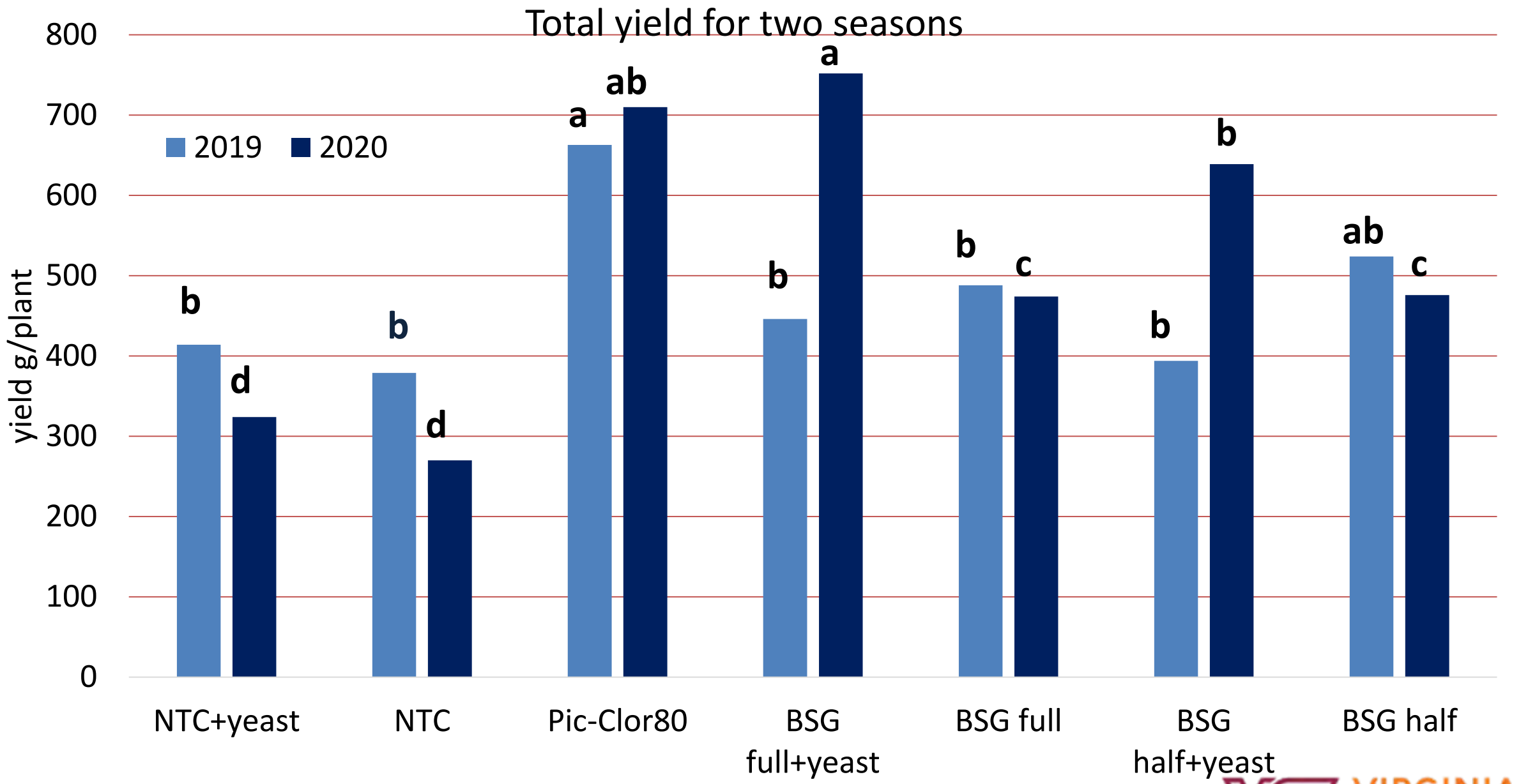
Total yield for two seasons
2019
2020
yield g/plant
800
700
600
500
400
300
200
100
0
b
d
b
d
a
ab
b
a
b
c
b
b
ab
c
NTC+yeast
NTC
Pic-Clor80
BSG full+yeast
BSG full
BSG half+yeast
BSG half

ASD, Challenges

Anaerobic soil disinfestation has high C requirements.

Use of composted waste as carbon source may introduce food safety issues.

Required duration of ASD treatments may be too long to fit into the current production schedule.

Nutrient leaching could be an issue in raised beds.

Treatment	Cost USD/ha
Fumigant (Pic-Clor60)	$2700 Note. Technical familiarity; requires a FMP; access to fumigant rig.
Anaerobic Soil Disinfestation	Material cost depends on C source. Ranges from free to $500/ha. Note. Labor cost for treatment application higher than fumigant.
Soil Solarization	$750
Mustard Seed Meal	$6323