

**Agrivoltaics -
combining solar
electricity generation
with crop production**

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What is Agrivoltaics?

- Agrivoltaics is the simultaneous use of areas of land for both solar photovoltaic power generation and agriculture.
 - Roof-mounted solar arrays installed on barns, farmhouses, greenhouses, or other farm buildings (roof installations on Mid-Atlantic farms?)
 - Ground-mounted solar arrays designed to meet on-farm electricity needs or serve the larger community (Current installations on poultry farms, other farms)
 - **Agricultural dual-use solar arrays designed to allow productive agricultural activities to continue under and between rows of solar panels** (few Mid-Atlantic installations)
 - Crops benefits?
 - **Shading** during critical growth stages to improve quality and yields
 - **Sheltering** to reduce crop damage from weather events

Issue – Solar Taking Farmland



Restrictions – Kent Co. DE Example

After months of public concern and hearings over the use of land in Kent County for solar panels, things seem to have settled down for now after Levy Court commissioners approved new restrictions that ban massive solar projects on farmland.

The amendment to an earlier ordinance, passed in September, prohibits new large-scale solar farms – those greater than 50 acres – on agricultural land. They are now confined to land zoned for general business, which cuts the potential area available from over 75,000 acres to around 1,500 acres, based on county staff estimates. That's a reduction of about 98 percent of available land.

The ordinance also spells out rules for smaller-scale, “community” solar projects, which are still allowed on agricultural land up to a point. The total acreage on county farmland devoted to these projects cannot exceed 1,600 acres.

Solution - Agrivoltaics



Fixed Solar vs. Tracking Solar



Some University Agrivoltaics Research and Outreach Programs in the US

- UMASS
- Rutgers underway
- Oregon State
- University of Arizona
- Illinois
- Auburn
- Purdue
- Colorado
- Georgia
- Now University of Delaware



Potential - Solar and Fruit Crops



Potential - Solar and Vegetables



Issue - Too Much
Shade

Grow between
panels, not under
panels



Shading Solution - Spacing



New tracker design for agrivoltaics

Spanish company Axial Structural is introducing a new type of tracker for agrivoltaic installations. The product can be adapted to various ground conditions and gradients, with programmable to optimize light and shade for different crops in different climates.

OCTOBER 15, 2021 PILAR SÁNCHEZ MOLINA

BALANCE OF SYSTEMS

MANUFACTURING

UTILITY SCALE PV

EUROPE

FRANCE

SPAIN



Shading Solution – Counter Tracking

CounterTracking™



- CounterTracking™ rotates the panels parallel to the sun, allowing sunlight to pass through to crops. This would be used sparingly, because panels aren't producing power while CounterTracking™.

Solution – Bifacial Solar Panels,



Shade Loving Crops, Utilizing Solar Shading

Limited by crops adapted to partial shading



Taking Advantage of Shading



Past UD Research – Shading and Rain sheltering

Solar panels could provide this!

- Pepper yield increased with shading
- Lettuce quality and marketability increased with shade
- Tomato fruit quality improved by shading
- Day neutral strawberry yield increased with shading
- Tomato cracking reduced by rain sheltering
- Strawberry diseases reduced by rain sheltering



Heat Effects on Fruits and Vegetables

Solar shading could help

- **Reduced Overall Yield**
 - Lower photosynthesis
 - Increased respiration
 - Reproductive failure
- **Reduced Quality**
 - Size and shape culls
 - Internal defects
 - Tissue damage
 - Tissue death
- **Mortality**
 - Premature senescence
 - Plant losses



Shade research shows the value



- Shade Cloth or Netting
 - Color
 - Black
 - Green
 - White
 - Alumninet
 - Percent Shade
 - 20-30%
- Natural shade
 - Intercropping

Shade Cloth for Bell Peppers

For green bell peppers planted in early June,

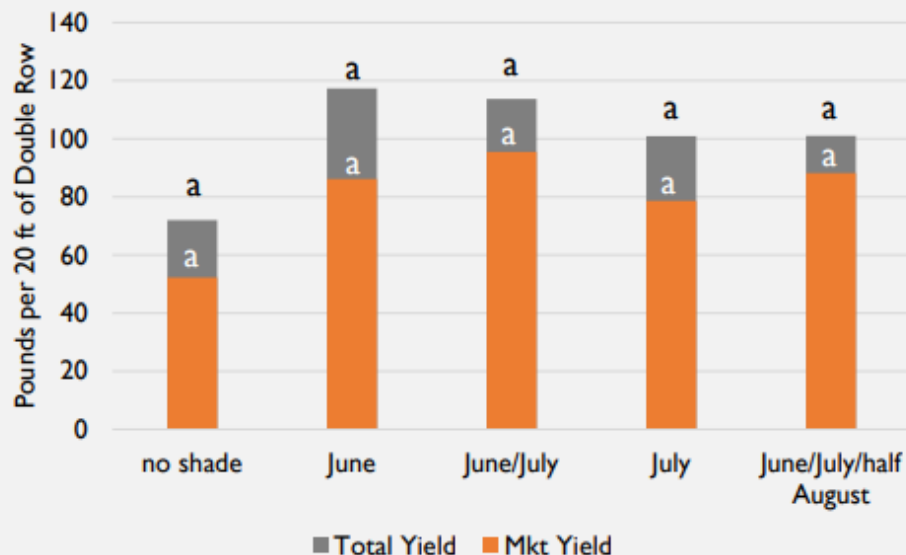
30% black shade cloth increased marketable yield:
3x the marketable yield of no shade!

30% black shade cloth increased the %
marketable weight from 39% to 67% marketable.



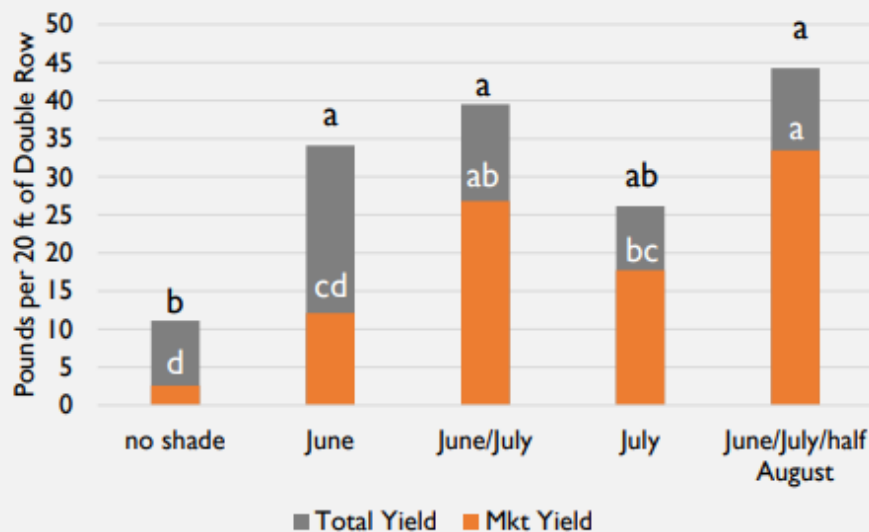
Shade Cloth for Bell Peppers

Carmen Total & Mkt Yield



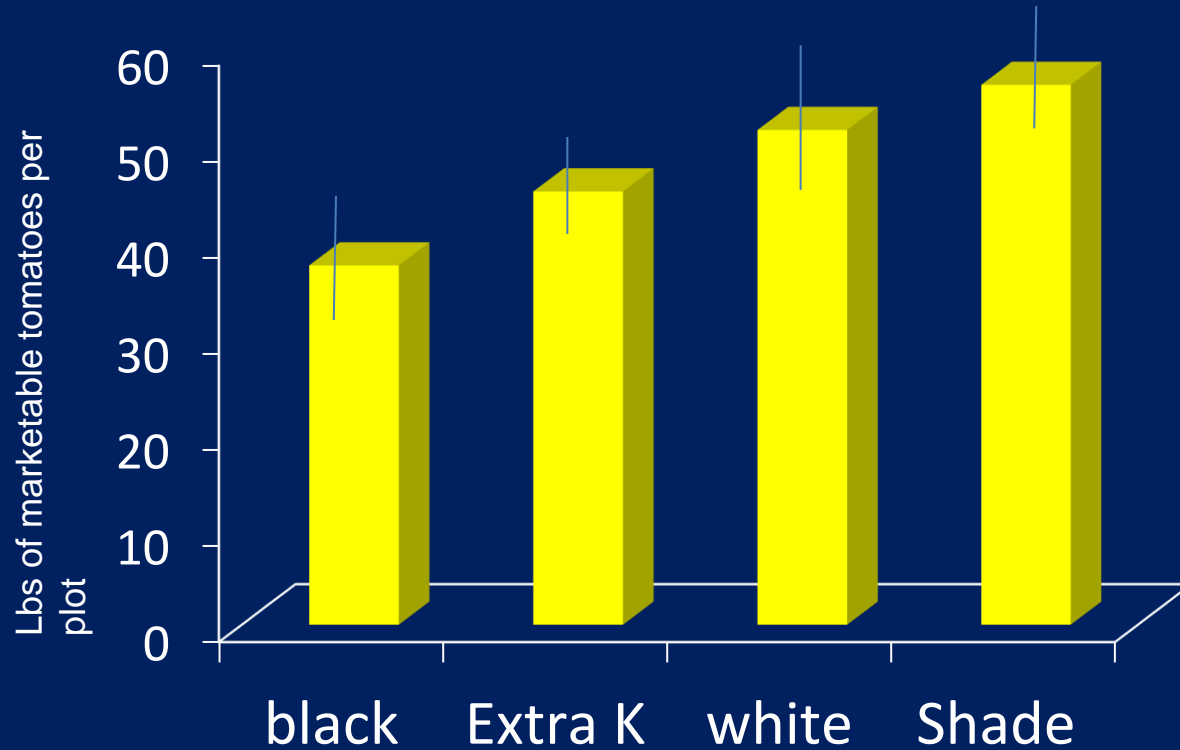
Shade cloth benefit for all bell varieties but not 'Carmen' the sweet Italian type.

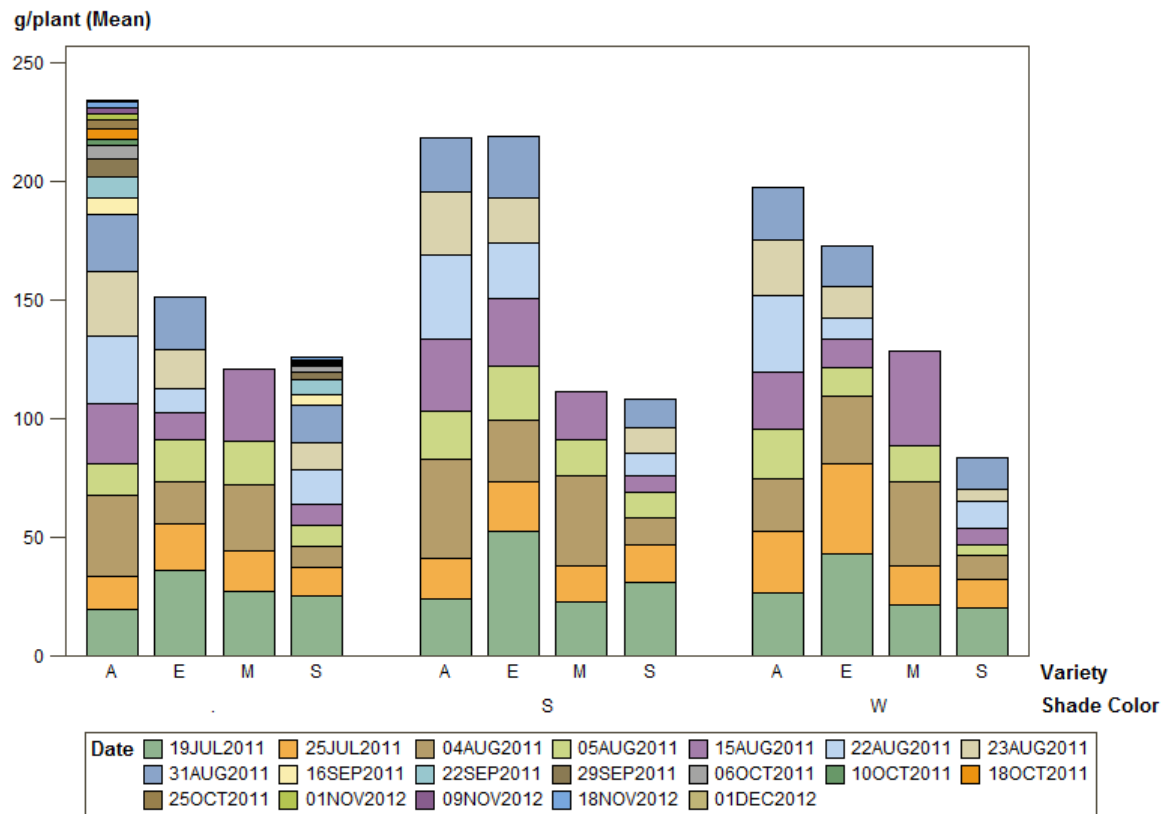
Bell Varieties Total & Mkt Yield



Shade cloth benefits most apparent if applied for June, July and half of August;
June & July most important

Tomatoes grown on different mulches, with extra K and under shade





S = aluminet shade, W = White
Shade

Taking Advantage of Rain Sheltering





C Smith, T.S. Smith & Sons

Could solar
panels
replace rain
shelters for
fruits and
vegetables?

Could solar panels shelter berries from rain like this low tunnel?



K Lewers, USDA Beltsville

College or Department name here

UD Agrivoltaics - Our Project and Project Vision

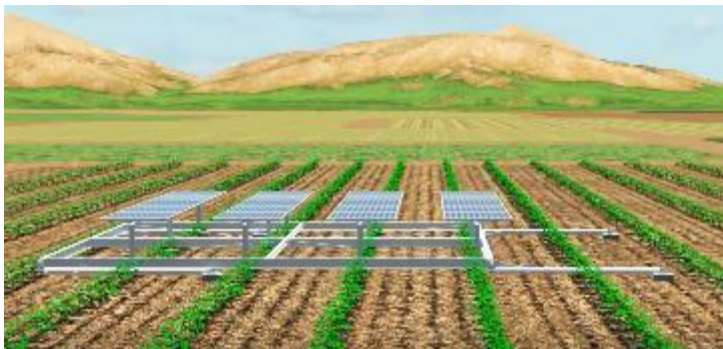
\$900,000 Unidel grant

- Installation of uniquely designed and precisely controlled tracking solar photovoltaic (PV) arrays for crop production research at UD's Newark and Georgetown farms.
- These two test sites will quantify the benefits of co-locating tracking solar arrays above high value crops to control seasonal shade schedules, while generating clean energy and additional agricultural revenue.
- As the climate becomes hotter and wetter, loss of vegetable and fruit crops will increase due to heat stress and damage from heavy rains. Many crops will benefit from shade and shelter of the solar panels due to lower plant temperature, reduced sunburn, improved fruit set, less water use, and reduced rain/hail damage.

System we are installing - SolAgra Farming And The Sunsharing Revolution



SolAgra Farming is our Patented Technology. This short animation shows you how it is constructed on the ground, hinged up into place, allows single axis tracking, counter-tracking, DynamicShifting from side to side, the UmbrellaEffect protecting crops and is modular.



Solar Platform Hinge Design

- The solar platform hinge design enables several features that improve not only install time, but also improve the ability to grow crops.





DynamicShifting™ And SunSharing™

- DynamicShifting™ the platform east and west allows farmers to control where the shadows from the panels fall on the field at any time of day, giving crops as much or little sunlight as desired, while continuously producing power, SunSharing™.



Single-Axis Tracking



- Single-axis tracking solar panels rotate throughout the day, keeping the panels perpendicular to sun in order to produce maximum power.

CounterTracking™



- CounterTracking™ rotates the panels parallel to the sun, allowing sunlight to pass through to crops. This would be used sparingly, because panels aren't producing power while CounterTracking™.

The UmbrellaEffect



- The UmbrellaEffect™ uses DynamicShifting™ to place panels above crops in order to protect them from unseasonal rain, snow or hail storms, These weather events would normally devastate crops.

UD Planned Research

- Shading timing, shading amount for sensitive high value vegetable and fruit crops: tomatoes, peppers, lettuce, and strawberries
- Rain sheltering effects on tomato and strawberry fruit quality
- Pest management effects under shade or shelter
- Water use under shading, water management under solar orientations
- Light management, light levels with different orientations
- Energy production under different orientations
- Control of orientations for shading and sheltering effects
- Partnership with Biden school to evaluate benefits from agrivoltaics



Questions?

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10 Years of Fresh Market Vegetable (and Fruit) Applied Research

Dr. Gordon Johnson
University of Delaware



Watermelon Pollination and Fruit set

- Field surveys
- Pollinizer studies
- Pollen viability
- Bees – Bumble bee, native



Watermelon hollow heart



- Limiting Pollen
- Fruit development
- Variety susceptibility
- Growth regulators
- Recommendations

Watermelon Disease

- Grafted watermelon-
Fusarium
- Phytophthora management
- Row middles
- Variety susceptibility
- No-till



G. Johnson, University of Delaware

Heat Stress Mitigation

- Varieties – Watermelon, tomato, broccoli
- Particle Film
- Growth regulators
- No-till



Soil health



- Compost – many vegetables and strawberries
- Cover Crops
- Biofumigants
- Rotations
- No-till, Strip till
- Inoculants

Variety Trials

- Watermelon
- Tomato
- Dual – pepper, beet
- Broccoli, specialty brassicas
- Brussels sprouts
- Squash
- Specialty pumpkins
- Onions – bulb and green
- Greens



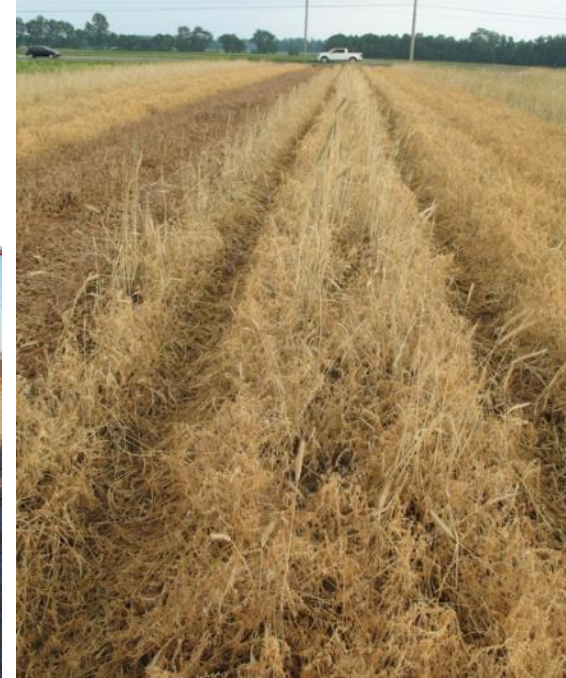
Fertility and Nutrition

- Nitrogen
- Potassium
- Calcium
- Magnesium
- Slow Release



Crop Management

- Irrigation rates
- Reduced Tillage
- Populations
- Planting dates
- Establishment
- Overwintering





New crops

- Baby Ginger
- Specialty pumpkins
- Specialty Broccoli
- Specialty greens
- Asian vegetables



G Johnson, University of Delaware

Fruit

- Day neutral strawberries
- Primocane blackberries
- Grapes
- Figs
- Persimmons



Specialty Cole Crops – Broccolini, Caulilini, Sprouting Broccoli, Gai Lan

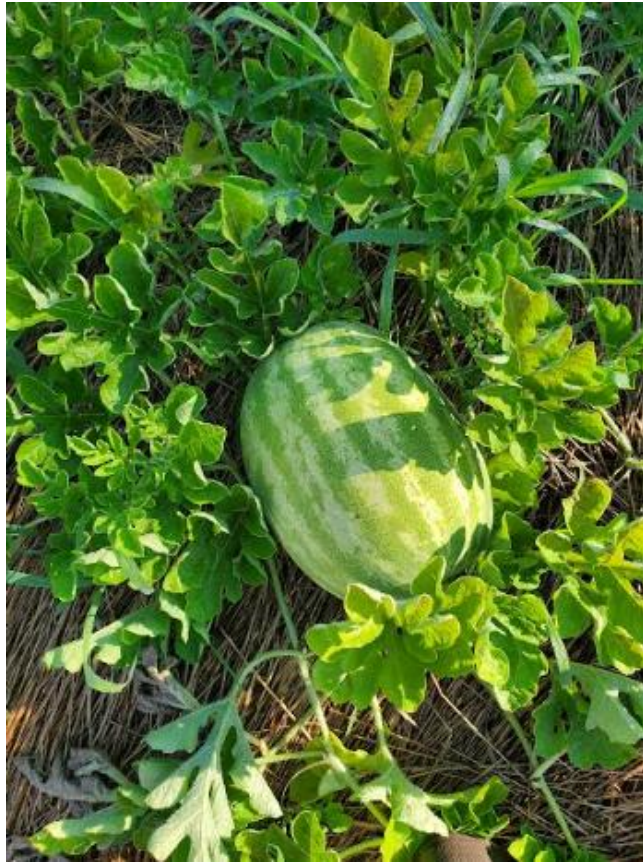












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EXTENSION

G Johnson, University of Delaware



Thank you!!

- I will be retiring in June
- Programs will continue - Dr. Emmalea Ernest will be your contact.
- Wish you all good fortune.

It has been a privilege to serve you for the last 12 years as Extension Fruit and Vegetable Specialist!

