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GLOBAL SCAN | AUGUST 2024

Looking Beyond Plastic Mulch Film

About Field Mulch

Field mulch, a physical soil covering, offers numerous advantages over non-mulched crop production systems, including:

- Preventing soil erosion by wind and water
- Increasing soil temperature
- Suppressing weeds
- Reducing water evaporation
- Preserving soil moisture

It therefore reduces input requirements and enhances crop quality, yield, and economic returns. Field mulches in vegetable and melon production generally fall into two categories: organic materials (plant products and animal wastes) and inorganic materials (synthetic options). Plastic Mulch Film (PMF) is the most widely used globally, including Australia, due to its affordability, durability, and versatility.

Figure 1: Melon field with PMF (Source: U Calvo)

OVERVIEW

Replacing Plastic Mulch Film (PMF) poses a significant challenge due to its low cost and immediate benefits. However, as input and production costs rise, concerns about climate change escalate, and policies regarding plastic use and waste evolve, finding alternatives to PMF is becoming increasingly important.

This global scan examines extensive research conducted globally and locally on alternatives to PMF, including:

- Soil biodegradable mulch film
- Organic mulches
- Emerging alternative: Sprayable Biodegradable Polymer Membrane (SBPM)
- Crop management practices such as living mulches, allelopathy, and reduced tillage

This global scan focuses on their effects on weed suppression, soil temperature, water conservation, yield, and crop quality.

Hort Innovation

This project has been funded by Hort Innovation using the vegetable and melon research and development levies and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

RMCG

ahr applied horticultural research

Impacts of Plastic Mulch Film

The effectiveness of PMF comes with significant environmental and soil health drawbacks, such as:

- PMF is a single-use plastic that is challenging to recycle due to high contamination levels with soil, organic matter, and agrochemicals
- Removal of PMF results in significant topsoil loss
- Even after removal, PMF leaves behind macro and microplastics (Figure 2) that accumulate in soils, landfills, and natural environments for decades. These particles can cause long-term negative impacts[1], such as:
  - Reduced soil water holding capacity
  - Decreased soil porosity
  - Harm to soil biology
  - Crop toxicity (leaf wilting, dead seedlings, and premature aging)
  - Costly and labour-intensive disposal
- In some cases, due to high landfill costs, growers resort to stockpiling PMF and either bury or burn it on their fields, releasing harmful substances into the atmosphere

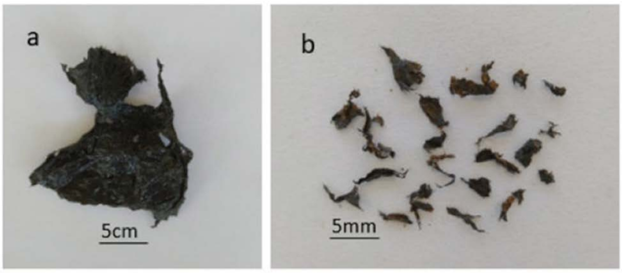

Figure 2: Black plastic mulch film left in the field after removal (a) macroplastic and (b) microplastic (<5mm) (Source: Mansoor, Z., et al.)

PLASTIC WASTE IN AGRICULTURE IS A MAJOR CONCERN

Each year, 10 million tonnes of PMF are used in agriculture globally. Approximately 90,000 tonnes of plastic are used in Australia, and it is estimated that just 7% is recycled[2]. In addition to PMF, other plastics used in agriculture include irrigation piping, nets, mesh, bagging, twine, poly tunnel films, and more.

Due to the large-scale use of plastic in agriculture the term 'plasticulture' has been coined, to better highlight this phenomenon.

Figure 3: Certified BDM made from Mater-Bi being applied in the field (Source: BioAgri)

Soil Biodegradable Mulch Film

Biodegradable polymers used in Soil Biodegradable Mulch (BDM) come from two main sources: (1) Fossil-sourced and (2) Bio-based.

BDM works similarly to PMF but has the added advantage of improving soil health. When incorporated into the soil, BDM is broken down by microorganisms into simpler compounds (water, carbon dioxide, and basic elements). Although BDM is more expensive than PMF initially, it helps address environmental and human health concerns. Additionally, it can reduce some of the costs related to labour and machinery needed for removing and disposing of PMF.

However, widespread adoption of BDM remains limited due to varying performance outcomes, high initial costs, unpredictable degradation rates and issues such as mislabelling or greenwashing (which undermine consumer confidence). These challenges widen the gap between awareness and adoption of BDM alternatives. Advantages and disadvantages of fossil-sourced and bio-based are summarised in Table 1.

Table 1: Comparison of fossil-sourced and bio-based products[3]

Polymer Type Category	Polymer	Advantages	Disadvantages
Fossil-sourced	Polybutylene adipate terephthalate	Good impact resistance and extensibility	Produces microplastics
	Poly ε-caprolactone	Flexible material and effective in retaining soil moisture	Degrades very quickly and has to be replenished frequently
	Poly Butylene Succinate	Good thermal stability	Expensive with limited biodegradability
Bio-based	Polylactic acid	Good processibility and thermoplasticity	Brittle and expensive
	Polyhydroxyalka-noates	Can act as controlled release system	Expensive to produce and lacks mechanical strength
	Chitin	Controls weed growth	Alters soil temperature and expensive to produce
	Alginate	Acts as bio stimulant and promotes plant growth	Rips after application
	Starch	Abundant and cheap	Brittle and low tensile strength so tears apart during application
	Cellulose	Flexible with good tensile strength	Expensive to produce on large-scale

There is a range of BDM available on the market, accessible in various countries (Table 2).

Table 2: List of commercially available BDM and their polymer type or polymer blend[4]

Trade Name	Polymer Type/ Polymer Blend
Bio 360	Mater-Bi® (TPS + PCL) + PBAT
BioAgri	Mater-Bi® (TPS + PCL) + PBAT
Biocycle	Sucrose/PHA blend
Bio-Flex	PLA/co-polyester
BiomaxTPS	Starch + TPS
Biomer L	PHA
Biopar	TPS and co-polyester
Biosafe	PBAT/TPS blend; PBS; PBSA
EcoFlex	PBAT; TBS
Ecovio	PLA; PBAT/TPS
Envio	PBAT; PLA; TPS
GreenBio	PHA
Ingeo	TPS/PLA; PBS/PLA
Mater-Bi®	PCL/TPS; PBAT
Naturecycle	Starch
Paragon	TPS
Renew	PHAs

Abbreviations: PBAT polybutylene adipate terephthalate; PBS polybutylene succinate; PBSA PBS-co-adipic acid; PCL polycaprolactone; PHA polyhydroxyalkanoate; PLA polylactic acid; TPS thermoplastic starch

CERTIFIED SOIL BIODEGRADABLE MULCH

Some mulch products on the market claim to be 'biodegradable', 'oxo degradable', or 'photodegradable'. However, they may not always degrade successfully, leaving microplastics in the soil[2].

In Australia, certified soil biodegradable mulches (Figure 4) must adhere to ISO 23517 *(2021 Plastics — Soil biodegradable materials for mulch films for use in agriculture and horticulture)* standards. These standards ensure complete breakdown in the soil, absence of microplastics, and no toxic residues.

Figure 4: ISO 23517 logo is administered by the Australasian Bioplastics Association (ABA), the peak industry body for the bioplastics industry in Australia and New Zealand (Source: Australasian Bioplastics Association)

Types of Organic Mulches

Organic mulches are made from living materials like plant and animal substances. The choice of organic mulch depends on factors such as cost, availability, durability, decomposition rate, and their impact on soil health and other properties.

Adding organic matter to soil can enhance biological, chemical, and physical properties. Despite the availability of various organic mulches, their adoption is limited due to higher costs compared to PMF, a steep learning curve, and greater labour intensity compared to inorganic mulches. Table 3 summarises the different materials used for organic mulches, along with their advantages and disadvantages.

Table 3: Summary of materials used for organic mulches, their advantages and disadvantages[1,4,5]

Type	Description	Advantages	Disadvantages
Straw 	Commonly used as an alternative to plastic mulch, and one of the key alternatives	• Moisture retention • Weed suppression • Reduces fertiliser leaching • Inexpensive and readily available • Biodegradable and environmentally friendly	• Can harbour pests and diseases • Can contain viable weed and grain seeds, with potentially a volunteer problem • As it decomposes, it can tie up nitrogen
Sawdust 	A by-product of wood processing	• Minimises water runoff • Minimises soil erosion • Suitable for acid-loving plants	• Inefficient in controlling weeds • Can tie up nitrogen from soil as it decomposes • Material hardens over time which makes it difficult for water to reach deeper into the soil
Paper mulch  (Source: University of Minnesota)	Paper mulches are made of cellulose-based materials and are applied as mulch layers	• Soil moisture retention • Weed suppression • With warmer seasons, heating the soil • Biodegradable unless other materials such as PE are added	• More expensive than plastic • Shorter life span than plastic and prone to tearing • Expands and contracts with drying and wetting cycles, causing issues for crops • Low resistance to environmental conditions

Type	Description	Advantages	Disadvantages
Wood and bark chips  (Source: University of Maine)	Used timber and a wide range of trees reprocessed / by-products of pine, cypress or hardwood logs etc.	• Retain soil moisture • Allow aeration • Good source of organic matter and C:N ratio	• Possible phytotoxicity • As woody materials decompose, phenolic acids are released, contributing to soil acidification
Deep compost mulch  (Source: No-till Growers)	Thick (2-3 inch) layer of compost applied on top of the soil and used as soil amendment. SWICP RESOURCES + Compost and soil structure	• Weed suppression • Increases soil biology and soil health • Adds nutrients to soil • Improves yield	• If applied close to crop stalks, it can absorb moisture, promoting pests and disease-causing organisms • Possible phytotoxicity
Spray-on wood fibre (hydromulch)  (Source: Australian Wood Fibre)	Wood fibre mixed with water and binding agents	• Erosion control • Weed suppression • Moisture retention • Keeps soil cool • Easy to apply	• Hardens over time • As it decomposes, it may tie up nitrogen

SWICP MELON DEMO SITE TRIAL EXPLORING ALTERNATIVES

The SWICP team are setting up a trial at Lakeland, Qld focused on exploring alternatives to PMF for melons, honeydews, and pumpkins. This initiative responds to rising costs and environmental concerns associated with traditional plastic mulching practices in tropical climates.

The trial includes testing the following treatments:

- Biodegradable plastic mulch
- Spray-on wood fibre mulch
- Cover crops: Sunnhemp, cowpea, French millet, white mustard, hairy vetch, millet + vetch or cowpea, cereal rye (low rate for woody stems)

STAY UPDATED ON THE SWICP WEBSITE

Beyond Plastics - An Emerging Alternative

Sprayable Biodegradable Polymer Membrane (SBPM)

Recent extensive research and technological advancements have led to the exploration of innovative solutions. Sprayable Biodegradable Polymer Membrane (SBPM) technology is gaining global attention for its ease of application and environmental benefits, emerging as a promising alternative to PMF.

What is SBPM?

SBPM is formulated using renewable, biodegradable raw materials or natural products. It consists of a water-based polyurethane dispersion resin that forms a coating when sprayed onto the soil surface (Figure 5). Growers can adjust the depth and width of application easily, providing flexibility. SBPM is biodegradable, biocompatible, and non-toxic, addressing plastic pollution challenges as well as reducing removal and disposal costs.

Figure 5. CSIRO's TranspiratiONal-SBM being applied to a tomato field trial (CSIRO)

How does SBPM break down and what are the benefits?

Biodegradable polymers are decomposed by soil microbes, releasing natural by-products like water, biomass, inorganic salts, and gases. Greenhouse and field trials indicate that SBPM can degrade over a period ranging from three months to one year, influenced by factors such as climate, soil conditions, and polymer properties[6].

Additional to the environmental benefits, SBPM enhances transpiration, suppresses weeds, and reduces water loss and nutrient leaching (Figure 6).

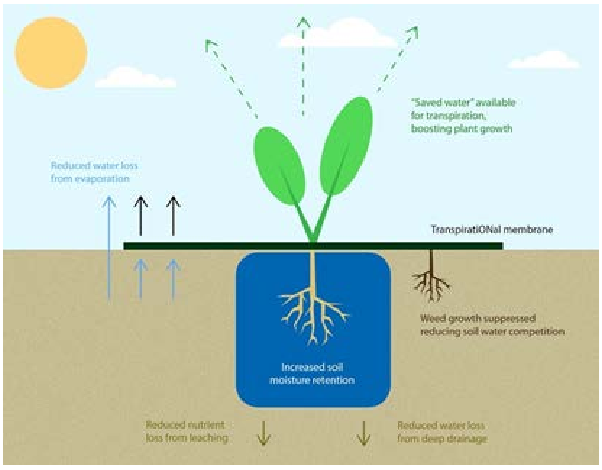

Figure 6: CSIRO's TranspiratiONal SBM technology and its benefits (Source: CSIRO)

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Evaluation of a Sprayable Biodegradable Polymer Membrane (SBPM) Technology for soil water conservation in tomato and watermelon production systems[6]

The Study: CSIRO has developed a biodegradable sprayable mulch, TranspiratiONal-SBM. Field-scale trials over two years were conducted with tomatoes at two CSIRO-cooperated sites near Echuca, VIC, and with watermelons near Finley, NSW.

The study aimed to assess SBPM technology's impact on:

- Soil water conservation
- Soil temperature
- Soil salinity
- Crop yield

Each site compared SBPM applied at various rates to standard farming practices: tomatoes used no mulch as the control, while watermelons used PMF as the control.

Figure 7: Application of SBPM in field scale experiment on tomatoes (left) and watermelons (Source: Braunack, M.V., et al)

The results:

- The higher SBPM application rates (1 and 3 kg m^{-2}) showed positive soil water conservation due its thicker application, reducing soil water evaporation
- Differences in soil temperature between most of the treatments were not significant. However, there was a noticeable increase in soil temperature under the highest SBPM loading (3 kg m^{-2}, non-fumigated)
- In the topsoil of tomatoes, the soil volumetric water content (VWC) was significantly higher for SBPM treatments compared with the control (no mulch)
- In the topsoil of watermelons, VWC was lower than the control (PMF) but higher in the next year with no crop. This is due to the consistency of the SBPM application compared to PMF, which can often tear and break
- Yields from standard practices and SBPM were not significantly different. However, the highest average yields were from crops grown under SBPM

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Effect of viscosity modifiers on soil wicking and physico-mechanical properties of a polyurethane based sprayable biodegradable polymer membrane[7]

The Study: Another two-year study at a CSIRO experimental site in Griffith, NSW, tested various polymer formulations in the laboratory and applied the preferred formulation in field on rockmelons and sorghum, comparing one SBPM treatment and a negative control, both receiving the same amount of irrigation.

The results: There was a significant reduction in soil evaporation in both laboratory and field trials. While crop yields were comparable in both treatments, the SBPM treatment used 28% less water, demonstrating improved water use efficiency (Table 4).

Table 4: Measured crop yield, water applied and water use productivity of melons in the field trial[7]

Treatments	Crop Yield (kg)	Water Applied	Water Use (kg/100L)
Control (Full Irrigation)	320	22,421	1.42
Polymer (28% less irrigation)	306	16,249	1.88
Control #2 (28% less irrigation)	250	16,249	1.54

Figure 8: Melon seedlings emerging through 'holes' in the polymer membrane (Source: Adhikari, R et. al)

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Biodegradable coverages for sustainable agriculture[8]

The Study: Sprayable mulch is currently under global development and trials. Two-year field trials were conducted at the University of Bari (Italy) and the University of Applied Sciences Osnabrück (Germany) (Figure 9). The objective was to assess different spray coating formulations compared to PMF (LDPE) and BMFs on various vegetable crops. Spray coatings must demonstrate comparable performance to PMFs to be widely adopted in horticulture production systems.

The results:

- The microclimate beneath the spray-coated beds was modified. Spray coatings raised soil temperatures, albeit slightly less than PMF. The highest temperature recorded occurred with BMF combined with chitosan-based spray material
- Generally, all treatments had a positive effect on tomato productivity. SBPM with organic matter *(Medicago sativa)* achieved the highest result
- Three months after treatment, PMF and BMF exhibited lower weed counts compared to SBPM
- The spray coatings were successfully buried and degraded in the soil

Figure 9: Spray coating obtained by polysaccharide mixture and carbon black (Source: BIOCOAGRI)

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Scientists and growers who have tested this technology believe SBPM could be a viable alternative to PMFs. However, further refinement is needed to improve its cost-effectiveness, sprayability, and durability[10]. Additionally, more long-term field studies are necessary to fully understand the impacts of SBPM on soil health, ecosystems, and the environment.

Figure 10: Mixed cover crops species used as living mulches to suppress weeds (Source: SWICP)

Beyond Plastics - Crop Management Practices

Crop management practices can provide the many benefits of field mulch while minimising plastic pollution and build long-term soil health. Such practices include:

Living Mulches

Living mulches, such as cover crops (cereals, grasses, legumes, or Brassica species), enhance soil health by adding organic matter and providing weed control. These cover crops are planted between successive vegetable crops (Figure 10), terminated, and their residue remains on the soil surface to create a weed-suppressing mat. The cash crop is then planted directly into this terminated cover crop.

In addition to enhancing soil health, integrating cover crops into vegetable production systems eliminates the need for mechanical removal or disposal costs at the end of the growing season, unlike PMFs. Benefits include:

- Weed growth suppression
- Pests and diseases management
- Reduces soil erosion
- Minimises soil water evaporation
- Contributes nitrogen to the soil
- Improves water infiltration
- Increases soil organic matter, which serves as a food source for soil microorganisms[9]

Weed suppression and crop yield vary in living mulch systems, which compete with vegetable crops for space, nutrients, and water. The success of vegetable and melon crops with living mulches hinges on the suitability of cover crop species, sowing dates, and effective control and termination methods.

SWICP RESOURCE

+ Replacing plastic mulch: Cover crops for weed suppression and soil health

Beyond black plastic[10]

The Study: The team at Rodale Institute and their grower partners conducted a three-year trial comparing cover crop mulches (rolled and mowed) with conventional plastic mulch films (PMFs) on tomatoes, other vegetables and melons (Figure 11). The trial focused on weed control, soil quality, fertility, yield, and waste production.

Cover crops tested included mulches of cereal rye, hairy vetch, and a rye/vetch mix. These cover crops were selected for their weed suppression capabilities (cereal rye), nitrogen-fixing capacity (hairy vetch), and a combination of both benefits (rye/vetch mix).

All treatments were managed following standard on-farm practices, including herbicide use and cultivation.

The results:

- PMF had lower soil moisture than cover crops. Soil temperature did not differ among cover crop species, but PMF had higher soil temperatures than both mowed and rolled cover crop treatments
- The rye and rye/vetch cover crop had double the biomass of vetch. The higher biomass resulted in better weed suppression on Meadow View Farm
- Achieving effective weed suppression requires compact soil cover, uniform mulch distribution, and careful consideration of termination methods. Weed biomass varied

between cover crops, while PMF showed consistent results; however, cover crops outperformed PMF in one year

- There was a slight increase in soil nutrient content, with carbon levels slightly higher in the rolled rye/vetch treatment compared to other treatments, though soil carbon and nitrogen did not change significantly

Figure 11: Butternut pumpkin growing in rolled rye and crimson clover on the Randolphs' farm (Source: Rodale Institute)

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SWICP RESOURCES

+ Managing cover crop residue in vegetable production - Factsheet

+ Cover Crops for Australian Growers

+ Cover Crop Herbicide Guide

+ Cover Crop Termination Guide

The Allelopathic Effect

Exploring cover crops for their allelopathic potential in weed management can be beneficial. Allelopathy involves organisms producing physiologically active substances (allelochemicals) under environmental stress, which can influence the growth, survival, and reproduction of other organisms.

In plants, allelochemicals can be found in various parts and released through root exudation, leaching, volatilisation, or decomposition of plant residues (Figure 12). Research indicates that plants with allelopathic properties can effectively control weeds, reduce herbicide usage, manage pests and diseases, regulate nutrients, and mitigate abiotic stresses.

Plants like Black walnut *(Juglans nigra L.)*, Sorghum *(Sorghum bicolor (L.) Moench)*, Wheat *(Triticum aestivum L.)*, and others are known for their allelopathic effects. Incorporating allelopathic crop species into agricultural systems through intercropping, cover cropping, crop rotations, and mulching shows significant potential for weed suppression. This approach is environmentally friendly and enhances efficiency in integrated weed management strategies[11].

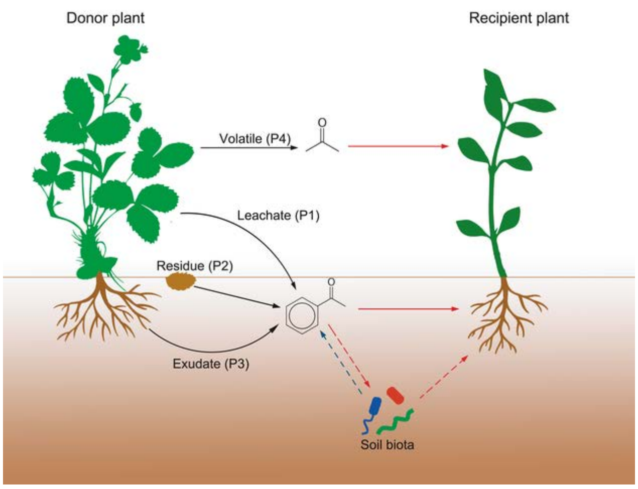

Figure 12: Allelopathic plants (left) release allelochemicals through four pathways (black arrows): leaching by rain (P1), decomposition of plant residues (P2), exudation from roots (P3), and volatilization (P4).

These chemicals can directly affect neighbouring plants (red arrows) or indirectly impact them via interactions with soil biota (dashed red arrows), which can also modify allelochemicals through conversion or degradation (Source: Zhang, Z et. al).

Reduced Tillage

Integrating cover crops with other regenerative agriculture practices can effectively control weeds and enhance the benefits of cover crops. Reduced tillage practices involve reducing tillage intensity, passes, depth, disturbed area, or eliminating tillage altogether (no-till). Research has found that cover crops in reduced tillage systems can provide weed control, resulting in a decrease in inputs, and improve crop yield.

The advantages and disadvantages of conventional and reduced tillage practices are summarised in Table 5.

Table 5: Reduced tillage and conventional tillage, its advantages and disadvantages

Type	Advantages	Disadvantages
Reduced tillage	• Improves soil health • Reduces topsoil loss from wind and water • Conserves soil moisture and improves water infiltration • Prevents nutrient runoff • Increases organic matter content • Lowers fuel and labour costs • Reduces the amount and size of tillage equipment	• Possibility of new pest species (which can be found in crop residue) • Crop establishment may require machinery modifications • Weed control can become more difficult due to less soil disturbance
Conventional tillage	• Risk of pest and disease carry-over is mitigated • Reduces the need for integrated crop protection methods • Successive crop can germinate free of competition • Warms soils quicker	• Disturbs soil • Physically damages soil structure and soil aggregates • Damages structural elements • Low water infiltration rates • Rapid runoff • Rapidly stimulates the breakdown of soil organic matter

Figure 13: Strip tillage, a method of reduced tillage in field (left) and strip tillage directly into cover crop (Source: SWICP)

Advancing reduced tillage for organic vegetable systems[12]

Ken Laing, a farmer-researcher at Orchard Hills Farm in Ontario, Canada, partnered with the Living Lab Ontario project. His organic farm has integrated cover crops for years to enhance soil health. Ken believes there's potential to further increase soil organic matter.

The study: Over three years, he conducted experiments with cover crop combinations and reduced tillage techniques for vegetables and winter squash, including planting and transplanting into winter-killed cover crops, green cover crops (before or after termination), and Deep Compost Mulch (DCM).

As Ken trialled many different combinations, the most promising findings included:

- Garlic thrived when planted into mown sorghum sudangrass cover crops (no-till)
- Potatoes showed promising results when planted into winter rye, mowed before potato emergence (no-till)
- Winter squash performed well with hairy vetch or deep compost mulch (no-till)

Figure 14: Winter squash transplanted into DCM on top of tilled soil (Source: EFAO)

Observations from the trials highlighted:

- Weed control effectiveness varied among cover crops. DCM (3/4 wood chips and 1/4 spent mushroom compost) proved most effective, though costly, followed by rye, sorghum sudangrass, oats/barley/peas, and daikon radish
- Winter-killed cover crops provided limited weed control. For instance, daikon radish decomposed quickly, leaving minimal residue, and sorghum sudangrass allowed weeds to germinate
- Transplanted crops generally showed better success than directly seeded ones
- Timing was crucial; delays occurred waiting for green covers to mature and be terminated by rolling
- The success of reduced tillage systems hinged on existing soil health

These insights from Ken's research offer practical guidance for implementing reduced tillage strategies in vegetable production systems.

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SWICP RESOURCES

+Reducing tillage and improving soil health with Mulgowie Farming Company at Maffra, VIC

+ Strip-till and cover cropping transform the Three Ryans' farm system

Tips to Get Started

Know Your Farm

Conduct a soil test, look at soil types across your field, the equipment, resources, and time you have to explore alternatives to plastic and crop management practices such as incorporating cover crops and reducing tillage.

Read and Learn

Knowledge is key to success. Read, learn and listen about cover crop species, reduced tillage, organic mulches, biodegradable mulches, and recycling options available so you can make an informed decision suitable for your system. You can also talk to other growers and take advantage of resources available on the SWICP website: soilwealth.com.au.

Test and Learn

Changing your current practices can be daunting but start small on a test plot. You'll understand and learn what practices and alternatives suit your system, as every system is unique. The issue of plastic use in agriculture is complex and it is not as simple as replacing one plastic product with a non-plastic product.

Ask Questions

Don't be afraid to ask questions – talk to your agronomist, seed suppliers, growers, and extension networks.

Summary

There are advantages and disadvantages to all field mulch applications, as each type of material has a specific set of characteristics. Unfortunately, there is no one-size-fits-all for a vegetable or melon production system, as every production system is different. Choosing one or more alternatives depends on your specific crop(s), climate, soil type, resources, and the sustainability goals of your operation.

Reducing plastic waste is a process and should involve experimenting with materials and practices, to find the most suitable choice for your growing system.

READ THE SWICP PROGRESS ON PLASTICS FACT SHEET

This fact sheet covers how you can recycle, considerations and the cost of BDM versus PMF.

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