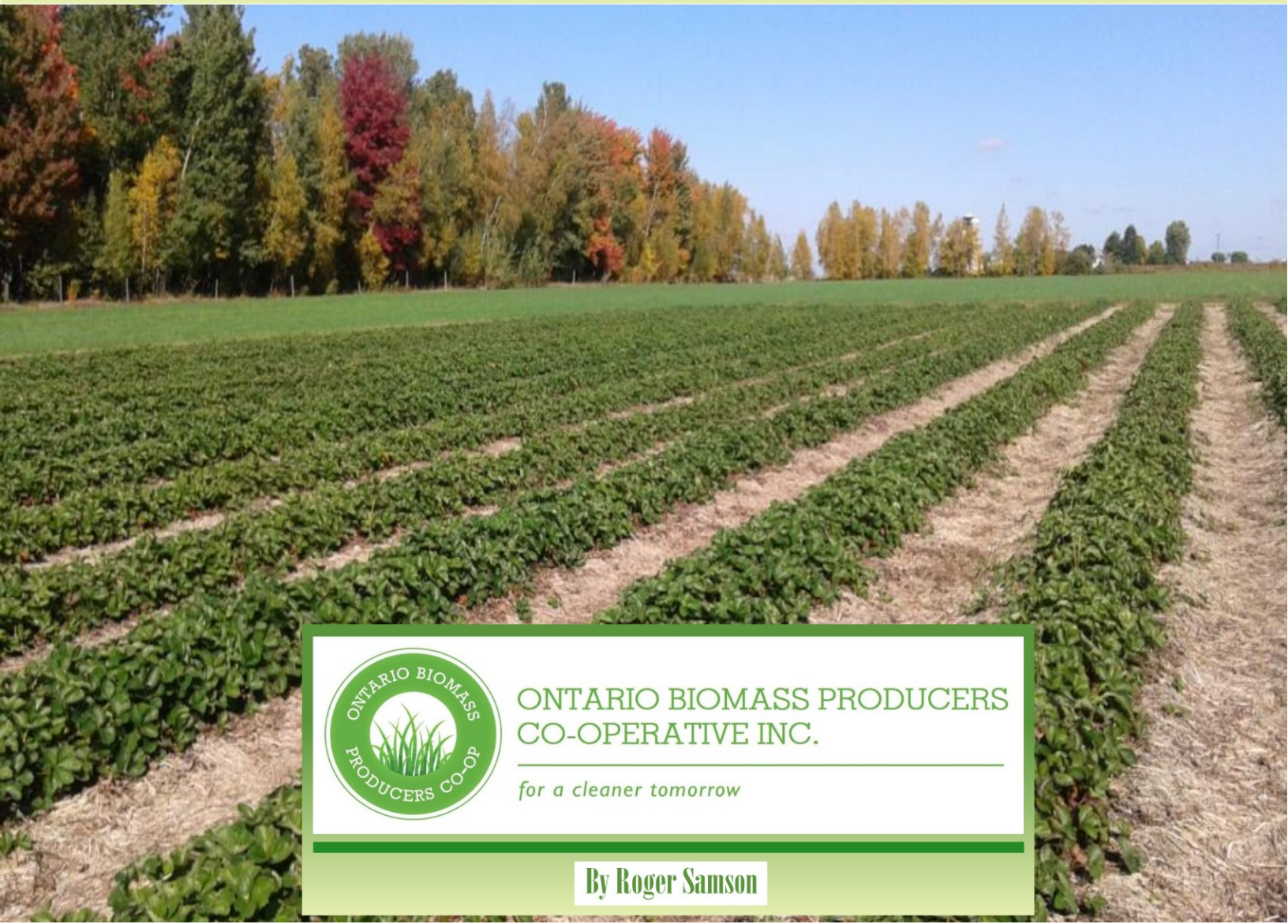
Using Switchgrass and Miscanthus as a Sustainable Mulch



ONTARIO BIOMASS PRODUCERS CO-OPERATIVE INC.

for a cleaner tomorrow

By Roger Samson

Acknowledgements

This document was developed with the support of:

OMAFRA-U of G Knowledge Translation & Transfer Program

Ontario Agri-Food Technologies

Ontario Biomass Producers Co-operative Inc.

June 2018

The Ontario Biomass Producers Co-op would like to thank the document developer for the effort to create this document.

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The 3 cover photos are courtesy of R. Samson, D. Nott, and N. Nadeau.

Introduction

The increased use of mulch in gardening and farming systems presents a promising opportunity to foster greater sustainability in our food and ornamental plant production systems. In nature, mulch is present nearly everywhere in productive ecosystems. It is especially abundant in temperate and tropical forests and on grassland savannahs. The slowly decomposing dead plant matter on the surface of the soil helps serve many useful ecological functions for helping manage soil fertility and increasing water availability to plants.

Mulch serves as food and habitat for a diversity of organisms, including beneficial soil microbes and insects. Warm-season grass mulch may also serve as a pesticide-free mulch for use on organic farms and gardens.

A well-mulched garden can help improve the appearance of a home. Furthermore, many people interested in sustainability are often drawn to permaculture gardening methods where mulching is a quintessential aspect of the production system.

Some of the benefits of using mulch include:

- helping prevent weed growth, thereby reducing manual weeding and/or the use of herbicides
- reducing evaporation
- moderating soil temperatures
- increasing water infiltration
- enhancing available water capacity
- preventing soil erosion
- slowly turning over nutrients to the soil
- enhancing soil organic matter, aggregate stability and microbial life
- increasing the winter survival of plants

The greatest contribution of warm-season grass mulch, however, is to the long-term sustainability of our soils. Prairie soils in temperate zones are among the world's richest soils, with much deeper soil profiles than nearby forested areas. Similarly, in the humid tropics, using decomposing mulch from sugar cane residues in sugar cane fields and from rice straw in rice paddies is one of the few ways of improving organic matter in tropical agricultural soils.

Finding new ways to use mulch from productive warm-season grasses in our gardens and farms could bring great benefits to increasing plant productivity and improving soils while also contributing to reduced watering and weeding needs.

This manual will explore the many benefits that a more sustainable mulch can bring to soils and plants, and discuss the principle ways of using switchgrass and miscanthus mulch. A key trait of these warm-season grass mulches is their slow decomposition, which is of paramount importance to their ability to provide long-lasting soil protection, effective soil carbon building and residual weed control.

Figure 1. Miscanthus is being used as a mulch to replace of winter rye on ginseng farms in Ontario. The main advantages are that it is slower to decompose and remains in place on the top of the beds. Ginseng beds are dug after 4 years so a more persistent mulch is a valuable trait. Traditionally growers apply a 10 cm thick mulch to start the beds and then re-apply each year as necessary. The mulch helps improve winter survival, keeps the soil cooler during the summer and helps retains soil moisture. A video of several growers developing ginseng mulching with miscanthus in Southern Ontario is available on Youtube. https://www.youtube.com/watch?v=LKOnHhx8c8E&feature=youtu.be

How Mulches Improve Plant Growth

Temperature Effects

Farmers and gardeners use mulch to improve the growth of their plants. People use organic mulches to counteract the effects of dry spells or heat stress on plants, whether the mulch is used on field crops, vegetable crops or ornamental gardens. Mulch has pronounced impacts on buffering soil temperatures by forming an insulative layer, thus creating smaller daily fluctuations in soil temperature.

Mulch keeps soil temperatures cooler in the day and prevents heat loss from soils at night by reducing outgoing heat radiation. The insulative effect of a warm-season grass mulch is optimized through the layering effect of a finer-chopped mulch. Warm-season grass mulch typically contains 45% cellulose in the whole plant and about 50% in the stem fraction. Cellulose is known to be an excellent insulator, which is why newspapers are used for wrapping frozen food for short-term transport.

Mulch also works to provide insulation by trapping air between layers of mulch. Air has a lower thermal conductivity than soil. A layer of mulch reduces the daily solar radiation absorbed by soils. Light-coloured mulches will absorb considerably less incoming solar radiation than a dark soil. Mulch also conserves soil moisture by preventing the wind from creating high daily evaporative soil moisture losses. The combination of high winds and lots of sunshine will rapidly dry out an unmulched soil.

A mulch will also cause seasonal temperature effects — the thicker the mulch, the greater the effect. Mulch can cause an appreciable delay in soil warming in the spring. In the summer, mulch will prevent soil temperatures from becoming excessively high through the day and moderate night-time soil temperatures. Light coloured mulches absorb the least solar radiation and will keep soil temperatures through the day the coolest. In the autumn period, mulch will retain warmth in the soil late into the fall, which encourages late autumn rooting.

Figure 2. On a hot summer day, a light coloured and cross layered warm season grass mulch will absorb less solar radiation to prevent the soil from overheating. The mulch benefits plant growth as it helps keep the plant roots growing in a cooler soil environment and it helps conserve soil moisture.

Farmers and gardeners should understand the various influences of mulch to optimize its use in their production systems.

The best results with warm-season grass mulches will generally be realized on crops that thrive in cool-to-warm conditions that are sensitive to excess heat and dry soil conditions, such as garlic, strawberries and blueberries.

Warm-season grass mulch used on a newly planted orchard may be an ideal application. It will reduce midsummer drought stress, watering requirements and moisture competition between young trees and weeds.

Mulch will also extend tree growth during cool fall conditions by maintaining warm soil conditions for rooting.

However, because mulch can cause an appreciable delay in soil warming in the spring, strawberry growers will clear the mulch off the beds and onto the walkways to encourage early strawberry growth.

Warm-season grass mulch use on heat-loving plants such as peppers or eggplant will provide less favourable results. Clear plastic mulches, which are effective in warming soils, may be a better choice for heat-loving crops.

Soil Water Availability

In ornamental gardens, mulches are highly favoured by gardeners to reduce watering requirements and help prevent flowering plants from wilting on warm summer days. The cooler and moister soil conditions created through the use of warm-season grass mulch tend to allow the plants to develop more surface rooting and be subject to less heat stress. The mulch also blocks sunlight from directly hitting the soil and tends to reflect more of the light hitting the surface than bare soil alone, resulting in less water loss.

Mulch reduces evaporation losses from soils as it forms a physical barrier consisting of overlapping mulch layers between the moist soil and dry air. By contrast, moisture will more readily be lost from soils if a chunky woody mulch is used. Wood mulch products tend to be less effective at holding in soil moisture, as the mulch is not as thoroughly layered, and water vapour can escape more easily.

Warm-season grasses make very effective mulch for trapping moisture, as they are highly effective at intercepting rainfall. Mulch will nearly always provide 100% soil ground cover. The mulch will intercept the rain and prevent droplets from directly hitting soil particles. On a flat-to-moderately sloping site, warm-season grass mulch will trap and quickly infiltrate nearly all the water from a moderate summer downpour. A bare soil offers limited potential to retain water. The water will rapidly run off and have little time to infiltrate. A downpour, especially on a sloping site, will often cause considerable amounts of fine soil particles to rapidly move off the site. Mulch works especially well in urban areas to help mitigate

flooding events by both reducing and slowing water volumes going into storm run-off collection areas.

An effective mulch will trap water on the surface of the soil, so that it can slowly infiltrate. Warm-season grass mulch is known to improve soil aggregate stability and earthworm channel formation, which also encourage water infiltration.

Mulch is effective in retaining water in the landscape in two ways:

- It allows moisture to pass through it to enter into the soil during a rainfall event.
- It forms a layered physical barrier to prevent water vapour from leaving the soil during evaporative periods.

As mentioned earlier, warm-season grass mulch should have a level of permeability that enables both sufficient water infiltration and sufficient gaseous exchange from soils to keep plants healthy and the soil from becoming waterlogged. Growers should use judicious levels of mulch (not more than 4 cm) on soils that are imperfectly drained.

The level of conditioning of the mulch has a major influence on its effectiveness in moisture conservation. Conditioning is the mechanical processing of biomass where the material is chopped to a shorter length and the stem split or fractured. Typically for garden mulching applications a 3-4 cm long material that has its stem split apart and stem walls crushed is well suited for most applications. This allows for good fibre cross layering but still retains adequate porosity for rainfall infiltration and gaseous exchange. Wood mulch tends to be chunky and have much greater porosity and less cross layering. It often sits on top of the soil and has less surface soil contact that warm season grass mulch that helps retain soil moisture.

Warm-Season Grass Mulches and Weed Control

The weed control benefits of warm-season grass mulch can produce outstanding results. There are three primary ways that warm-season grass mulch works to help suppress weed growth:

- It acts as a physical barrier.
- It manipulates the availability of surface soil nutrients.
- It creates improved growth and the competitive ability of the plants, shrubs and trees being grown.

Physical Barrier Impacts

Mulch has a strong impact on the amount of light reaching the soil. This can be a very important measure for preventing seedling emergence of certain weed species.

Many weed seeds have evolved a light requirement for germination. Studies have found that small-seeded species in particular have a strong light requirement. Small-seeded species have limited seed energy reserves and generally have much greater difficulty emerging from soils. As a result of these low seed energy reserves, small-seeded weeds have evolved a light requirement to help ensure success in emergence. By contrast, large-seeded species are generally much less light dependent for germination.

If mulch is adequately conditioned and applied in sufficient quantities, it can cross layer to completely block the sunlight from reaching the soil. Sunlight hitting soil can only penetrate several millimetres into the soil.

A sufficient depth of mulch over the soil will completely block out the light trigger for germination of small-seeded weed species. Generally, 3–4 cm of a cross-layered mulch is sufficient to prevent small-seeded annual weeds from emerging. The weeds affected can include important small-seeded annual weeds such as lambs quarters, pigweed and crabgrass.

It is evident that warm-season grasses will work very well as mulch, as they decompose much more slowly than cereal straws. As well, grasses with thin stem walls, when chopped, will provide a much better layering effect to prevent sunlight from penetrating soil than chunky wood mulch products. Wood chips and bark are generally much less effective at suppressing weeds, on a weight basis, than warm-season grasses, as woody mulch tends to be produced in thicker pieces that have a higher bulk density. Grasses are hollow and have thin stem walls, which tend to more effectively cross layer to block light. Switchgrass tends to be superior to miscanthus for this, as it has a thinner stem and a thinner stem wall to promote cross-layering.

Figure 3. Wood residue mulches tend to grow more weeds than well conditioned warm season grass mulches as they do not cross layer as effectively. Wood mulches also can acidify soil which can be harmful to some plants.

Manipulation of Soil Nutrients for Weed Control

The second way that mulch from mature warm-season grasses suppresses weed growth is by modifying soil nutrient availability at the soil surface.

High-carbon mulches such as switchgrass and miscanthus typically have a carbon content of 45% and a nitrogen (N) content of 0.2%–0.4%. This results in a high C:N ratio mulch of approximately 100–225:1. When the mulch is applied to the soil surface, the microbial biomass in the soil feeds on the carbonaceous material and gradually increases in number. As the mulch itself is very low in N, the soil microbes need to uptake available soil N to decompose the high carbon mulch. Microbes are much better competitors for available soil N than plants. They extend fungal hyphae (or threads), which are more efficient than plant roots in scavenging the surface soil for nitrogen. Microbes will efficiently deplete available soil N as they increase in number.

This process is known as N immobilization and is a better explanation for the weed-suppressing effects of high-carbon cover crop mulches (e.g., winter rye) than allelopathy (a chemical inhibition from plant residues on germinating weeds).

The N, however, will only be temporarily immobilized by the microbes, if the carbon food sources run out. When the microbes die off, they subsequently release the N back through the mineralization process into the available soil N pool. This temporary immobilization of N caused by application of high C:N ratio mulches can play a very effective role in suppressing weeds, especially in the spring.

A more recent discovery is that fungal hyphae also play a role in transporting available soil N directly to the mulch on the surface to enhance its decomposition. Thus, the combination of N immobilization by the soil microbes and the transport of available soil N by fungal hyphae to the above-ground mulch work together to deplete surface soil N. Weeds that develop from small seeds are most affected, as they are highly reliant on soil nutrients for early plant development. Small-seeded weed species will rapidly exhaust seed energy reserves to support growth, if soil nutrients are lacking.

Mulch applied in the spring is highly effective at suppressing weed growth when weed germination and growth are most prolific. The effects of the physical effect (blocking sunlight) and surface nutrient immobilization are additive and can completely smother out most annual weeds. High N-dependent small-seeded annual weeds, such as lambs quarters and pigweed, tend to be most affected.

The technique works best with certain types of vegetable crops that have low nutrient demands and grow well in cooler soils such as garlic, peas and beans. It is less well suited for use in vegetable crops, such as broccoli, that require high levels of available soil nutrients. In the case of high-nutrient-feeding brassicas or potatoes that like cooler temperatures, use of a hay mulch or lawn clippings will provide more favourable growth impacts on the crop. For heat-loving crops, such as hot peppers, eggplant or cantaloupe, a plastic mulch would be a better choice for optimizing both crop response and weed control.

Weed control using a warm-season grass mulch tends to work exceptionally well with deep-rooted perennials, including many types of perennial vegetables, perennial flowers and shrubs. The technique works extremely well for prairie gardens and ornamental shrubs, as they have much deeper root systems. Producers of strawberry, blueberry, asparagus, garlic, ginseng and other high-value crops are having great success using warm-season grasses as a weed control and growth-enhancing mulch cover.

Warm-season grass mulch can also bring benefits for control of perennial weeds. However, the mulch's main role will be in preventing the establishment of perennial weeds rather than controlling existing populations. To control populations of perennial weeds, much larger quantities of mulch (as much as double) will have to be applied than the 3 cm of mulch that may be required for annual weeds. The one caution of using switchgrass mulch is that in a long term crop such as asparagus, self seeding of switchgrass can be a problem for organic farmers. Miscanthus biomass crops would be a safer choice for organic growers to alleviate self-seeding concerns.

Use of larger quantities of mulch, however, brings greater risks to the plants. For example, the excess use of mulch around trees to create "mulch volcanoes" is known to create detrimental impacts on plant growth. It can block the air exchange with the soil and create soil oxygen depletion. Thick mulch can also attract rodents around trees. Thicker mulches may only be successful on well-drained, coarse soils. Soils that are clay soils or poorly drained should never have a thick mulch application, as excess water may accumulate and low oxygen content in the soil will occur. For nearly all types of mulches, once the mulch exceeds an 8-10 cm application, there are no incremental beneficial impacts on plants to be expected and the odds increase for a negative impact.

Figure 4. Effective use of a 2-3 cm chopped natural switchgrass mulch as a coloured wood mulch replacement.

Impact on Diseases

Mulch use can increase the risk of disease in three principle ways:

- The mulch may be infected with a disease that is transmissible to the desired crop or shrub.
- The mulch is finely processed and/or thickly applied and continually maintains a high humidity environment in the mulch layer.
- The mulch layer is too thick or too fine, preventing oxygen exchange with the soil.

Mulch as a Host of Disease

Generally, warm-season grass mulch is safer to apply on plants than woody or cereal straw mulches. While the risk of disease transmission by mulches to the cultivated crop or garden species is generally considered low, it nonetheless does occur. Warm-season grass mulch is a safer choice for mitigating the risk of disease transmission, especially from the mulch to woody species that are not close relatives. In the case of some high value crop species, warm season grass mulch has been found to be a less effective host for transmission of disease than cereal straw. Cereal straw is a common host to fusarium, which is a problem for ginseng and other high-value crops. Thus, grasses such as switchgrass and miscanthus can help reduce disease transmission risks compared to wood-based or cereal-straw mulches.

Mulch Creating Excessively Humid Environments

One of the benefits of mulch is that it conserves moisture in the landscape. However, growers should be aware that finely processed mulch, warm-season grass pellet mulch (made of ground fibre of 5mm or less that is compressed and densified) or thickly applied mulch can create an environment more conducive to disease development.

Figure 5. Researchers and gardeners have found switchgrass mulch applied in a pellet form expands well with moisture to smother weeds but will generally form a crust and crack. The best use of pellet mulch is likely as a cover for nursery pot containers used for growing trees and shrubs where highly effective residual weed control is required.

A noteworthy problem with the use of warm season grass pellet mulch is the growth of colourful slime moulds that grow in a sheet over the mulch surface.

These moulds are frequently observed with the use of warm season grass pellet mulches during summers of high rainfall and humidity. In a worst-case scenario, these aesthetically unappealing slime moulds can completely cover the surface of the mulch and can even climb up garden plants and kill them. If they do occur, the best way they can be controlled is by raking the mulch surface to encourage moisture and oxygen exchange with the soil.

To avoid slime moulds, use a warm-season grass pellet mulch in combination with a chopped straw mulch for ornamental garden applications, or not at all. A pellet mulch can often create a hard surface that does not facilitate water entry or gaseous exchange. Pellet mulches are also less attractive than a 2–3 cm chopped mulch placed around plants. Once pellet mulches absorb moisture, they rapidly expand, and the small fibres adhere together when drying to form a crust. The

crusted layer traps moisture in the mulch and prevents water from infiltrating quickly during a rainstorm event. A crusted pellet mulch can also form large cracks, which are not very visually appealing. The main advantage of a switchgrass pellet mulch is that it provides outstanding weed control. However, it is best avoided unless used in well-drained containers, in low-rainfall environments, in row applications in gardens or in a surface mixture with chopped warm-season grasses.

In the case of shrubs and trees, it is widely advised to avoid excessively thick mulches (i.e., greater than 8 cm) and not to apply mulch within 15 cm of a trunk, let alone up against the trunk. Tree trunks are not used to being in constant contact with moisture. Mulching against the tree can cause it harm as it may prevent the normal respiration processes of the trunk by limiting CO_2 and O_2 exchange. Too much mulch can also favour the development of root rots and fungal cankers. Mulch may also favour moisture-loving insects such as carpenter ants if placed against a tree trunk. Coarse straw mulches often are used as habitat for mice. Tree guards should be placed around young trees to prevent mice from chewing the bark during winter. Tree guards are also useful for preventing damage from grass trimmers and mowers.

Soil Oxygen Depletion

Another common problem with the excessive use of mulch is that anaerobic conditions can occur in soils. This problem is highly detrimental as it can affect nutrient availability, stunt rooting and encourage many diseases that thrive in anaerobic soil conditions, such as fusarium and anthracnose. Applying a thick and finely processed mulch that completely seals the soil surface from gas exchange creates an environment that is unhealthy for plant growth. Generally, a medium-textured warm-season grass mulch of about a 2–3 cm chop will help adequately suppress weeds while enabling good air exchange with the soil. Mulches should be applied carefully, especially on poorly drained clay soils, where they are best applied later in the spring when the main period of extended soil saturation has passed.

Mulch Effects on Soils

One of the most desirable aspects of the long-term use of warm-season grass mulch is its highly beneficial impact on soils. There are modest effects on improving long-term soil nutrients, but the biggest impact is on soil aggregate stability and soil organic matter formation. Farmers who grow their own mulch will also realize these soil-building benefits in their warm-season grass production fields.

Soil Nutrients

Repeated application of warm-season grass mulches can enhance the nutrient status of soils. For example, an overwintered switchgrass crop harvested as mulch will typically contain 0.05% phosphorus (P) and 0.10% potassium (K). Thus, if a 10–20 t/ha annual application is made, the mulch will contribute 5–10 kg/ha of P and 10–20 kg/ha of K to the soil annually. The warm-season grass mulch also serves as a source of calcium and trace minerals. Grass clippings and hay mulch are a much better source of nutrients for building soil nutrient levels in gardens or fields.

The biggest impact of warm-season grass mulch on improving plant-nutrient status will be indirectly through improving soil properties such as aggregate stability, soil organic matter and soil biological processes. By enhancing soil properties to enable deeper rooting, mulches create conditions that enable plants to scavenge adequate levels of nutrients to produce abundant crops. At the same time, warm-season grass mulches encourage the soil food web to function well (for example, by enhancing earthworm activity) to release nutrients. Encouraging better root systems on plants and creating a more functional soil food web will work together to help plants access the necessary nutrients to optimize growth.

Soil Formation Under Warm-Season Grass Mulch

The processes that lead to changes in soil properties under warm-season grass mulches are becoming better understood. As mentioned earlier, mulches can play important roles in increasing soil microbial biomass, increasing soil aggregate stability and contributing to the long-term development of soil organic matter in soils. Mulch has an important role in helping optimize the soil formation processes:

- It eliminates cultivation processes that destroy soil aggregates.
- It acts as a carbon source to stimulate microbes that produce binding agents.
- It helps support large populations of earthworms, which consume and excrete micro-aggregates.
- It contains phytoliths or plant stones, which are carbon sources that are highly resistant to decomposition.

Microbial Biomass

The microbial community in the soil is mainly composed of fungi and bacteria. The fungal-to-bacterial ratio of a soil is strongly affected by both soil management and the type of carbon additions added to the soil. Tilled systems tend to have a larger content of bacteria in the microbial biomass. Bacteria in the soil, by contrast, will respond much more favourably to high N additions such as an N-rich green manure.

Grassland soils are the opposite; they tend to be heavily dominated by fungi, as they are undisturbed systems and have large annual additions of high-carbon mulch. Fungi are microscopic cells that can develop long strands or threads called hyphae. The hyphae can push their way between soil particles, roots and rocks and also extend above ground into decomposing mulch. The tillage process is very destructive to fungi, as it disrupts the network of fungal hyphae in soils. Application of relatively high rates of warm-season grass mulch to an undisturbed soil is highly compatible with increasing fungal activity in soils.

Figure 6. Decomposition of native warm season grass mulch on soils can bring tremendous benefits to improving soil aggregate stability. Fungi dominate grassland soils and are ideally suited to decomposing high C:N-ratio warm-season grass mulch. Fungi also play an important role in the initial stages of soil organic matter formation by developing a network of fungal hyphae or threads around soil particles.

Fungi are ideally suited to decomposing high C:N-ratio warm-season grass mulch. Fungi have C:N ratios between 7:1 and 25:1, and therefore require a great amount of carbon to grow and multiply. By contrast, bacteria typically have a C:N ratio of between 5:1 and 7:1 and need more N to meet their growth requirements. Warm-season grass mulch is typically composed of 45% cellulose making it an ideal food for fungi. To access this material, fungi will extend hyphae into the litter layer to help begin the decomposition process of newly added mulch surface residue. One reason for the higher carbon demand of fungi is the composition of their cell walls. The walls are made up of polymers of melanin and chitin, which helps make them very resistant to degradation. By contrast, bacteria are made up of energy-rich phospholipids. Bacteria are much more readily broken down and can serve as a food source for a diverse array of soil microorganisms.

It is difficult to precisely describe the mechanisms of soil aggregation and soil organic matter formation, as there are many inorganic and microbial processes that

are contributing to this complex process. However, it is increasingly recognized that fungi play an important role in the initial stages of the process, especially in one of the first steps in soil organic matter formation: fungi extending their fungal hyphae in soils. The hyphae will eventually mesh together soil particles and form linkages between them, which they subsequently re-enforce. This initial process is then followed by bacterial secretions, which internally reinforce the strength of the macro-aggregates created by the fungal hyphae.

Earthworms

Earthworm levels also generally increase under mulches. This is due to a lack of soil disturbance, an abundance of decomposing organic matter, cooler surface soil temperatures and higher soil moisture levels in mid-summer. Earthworms help form soil aggregates in two ways: burrowing and cast formation.

When earthworms burrow, they exert a pressure on the surrounding soil and deposit an external mucus on the burrow walls. A stable structure is often formed from the organic mucilage and oriented clays.

Studies have also shown that earthworm casts have a higher stability than in the surrounding soil aggregates. The stability of the casts depends on the quality of the ingested organic matter, and the volume of castings produced depends on the feeding activity. Clay minerals and organic materials are intimately mixed during transit through the earthworm gut. The mixture also becomes encrusted with mucus while passing through the gut, which enables earthworms to continually excrete new micro-aggregate formations into the soil. The micro-aggregates generally form within the macro-aggregates created by the fungal hyphae.

Phytoliths

Another important factor at play in building soil quality is the presence of phytoliths in grasses. Warm-season grasses such as switchgrass and miscanthus are known to contain high levels of phytoliths (plant stones) in their biomass. Phytoliths are formed in plants through the uptake of silicic acid from soils. The plant silica

phytoliths or silicified plant cells are produced in great numbers in warm season grasses and are commonly formed in the leaves. Typically, grasses will have six times the quantity of phytoliths in their biomass than woody plant species. Phytoliths are highly resistant to decomposition, are extremely slow to be decomposed and can last for very long periods (~1,000 years). Thus, mulching with warm-season grasses may be a promising long-term strategy to slowly but steadily increase soil carbon. One reason the tall grass prairie zone of North America has the deepest and richest soils in North America is the long-term build-up of phytoliths in soils. They are a dominant component of the high levels of soil organic matter found on prairie soils. Typically, a Midwestern prairie will have nearly double the soil organic matter of a nearby forest soil. Thus farmers and gardeners applying warm-season grass mulch to their horticultural crops are making valuable contributions to the long-term soil organic matter build-up of their farm or garden.

When the mulches decay, the phytoliths are deposited on the surface of soils. Eventually phytoliths end up being bound in the organic and inorganic components of soil. When soil moves, as a result of burrowing animals, wind or water (both percolation and run-off), phytoliths are also dislocated. Where high earthworm activity occurs, large movements of phytoliths can occur. Studies have found that, on average, through these various mechanisms, phytoliths newly deposited on the surface can move 4 cm in 1 year. Small phytoliths in particular have the ability to move substantial distances. Earthworms can typically ingest 4%–10% of the surface horizon per year. Through earthworm consumption and excretion of phytolith-containing soils, phytoliths are readily mixed into the soil surface horizons.

It appears prairie grass mulch has a number of mechanisms for creating a very efficient system to build soil fertility. It is well known that forest soils have a relatively thin topsoil layer in the very same environment where prairie grasses can produce a deep soil profile. It may be that the differences in large annual production of high carbon mulch, higher presence of fungal microbes and the larger annual production of phytoliths are important factors contributing to prairie soils being very efficient at soil carbon storage processes.

Guidelines for Using Mulch Successfully

- Eliminate perennial weeds from the site prior to mulch application.
- Ensure the mulch is free of weed seeds and has limited self seeding (especially for use on long term perennial organic horticultural crops).
- Ensure the mulch is sufficiently porous so it does not stay in a constant wet state and encourages fungal growth.
- Keep the mulch 15 cm from the base of woody shrubs and trees to prevent disease and pest problems.
- Apply appropriate quantities of mulch (not more than 8-10 cm), at an appropriate time.
- Use mulch material that will not readily break down and will last at least one season.
- Apply the mulch to a freely draining soil, not subject to saturation.
- Do not use a high C:N mulch on a crop with a high nutrient demand and shallow root system (see pg 15).
- In garden applications, use well conditioned warm-season grass mulch that is chopped to a 2.5-3 cm length and apply it at a depth of 2.5–4 cm to provide adequate cross layering to create a light suppressing thatch, providing highly effective physical weed control effect. (Small-seeded weeds have a strong requirement for light to trigger germination.)
- Apply a high C:N ratio mulch to create a nutrient immobilization effect on annual weeds (expect the greatest impact on small-seeded annual weed species).
- Use larger quantities of mulch on free-draining soil if weed suppression of perennial weeds is targeted.
- Expect small-seeded annual weed species that are light and soil-nutrient dependent to be most controlled by mulching.
- Expect deep-rooted perennial weeds, such as thistle or milkweed, to be least affected by mulching (other supplementary measures will have to be taken).

Mulch Application

The application rate of warm-season grass mulch will depend on the intended use. Higher application rates will generally be more applicable to ornamental gardens, while lower rates are used for commercial horticultural field production. In both instances, mulches can exhibit tremendous impacts on enhancing soil properties for plant growth. Studies examining annual applications of wheat straw on soil found that a mulch rate for achieving most of the beneficial soil effects was approximately 8 t/ha applied annually over a 10-year period. This rate was found to appreciably increase available water capacity, field capacity, aggregate stability and total porosity. The rate of 8 t/ha is approximately the annual growth increment of a productive native prairie grass stand and about double the biomass produced from a winter rye cover crop.

For effective weed suppression, even higher application rates may be used by gardeners, using warm-season grass mulches. For example, the bulk density of switchgrass mulch chopped to a 2.5-cm length and applied to soil is approximately 65 kg/m^3. For every 2.5-cm layer applied to the soil surface, approximately 1.7 kg of mulch/m^2 is applied. Typically, for weed suppression, most gardeners would apply annually about a new layer of 2.5–4 cm of mulch to the soil or about 1.7–2.6 kg/m^2. A 15-kg bag of mulch would cover about 6–9 m^2. This would represent about 22 t/ha of mulch. In the first year the higher end of the range of 2.5-4 cm thickness can be used and in subsequent years the lower end of the range can be applied as the garden will have residual undecomposed biomass.

The 2.5-4 cm thick layer contains a very large amount of biomass to slowly decompose to contribute to the soil-building processes. It can be seen that warm-season grass mulching represents a very promising strategy to quickly improve soils when these high rates of application are used annually.

Gardeners, when calculating their mulch requirements, should take into account the space occupied by shrubs or perennial flowers in a bed. It is best to apply thin layers or no mulch to the immediate area over most garden plants.

Figure 7. A well conditioned warm season grass mulch applied to 2.5 cm thickness (the thickness of a hockey puck) will provide adequate cross layering to eliminate the growth of most annual weeds. This represents an application rate of approximately 1.7 kg/m^2 per or 17 t/ha of switchgrass mulch. Slightly higher rates can be used in the first year when setting up the garden.

Many homeowners prefer a mulch that does not contrast excessively with the colour of the house. This is an important consideration for many homeowners and mulch providers should be aware of this consumer concern. Overall, lighter-coloured grass mulches work very well with lighter-coloured homes. Most homeowners with darker-coloured homes prefer more earth-coloured mulches, hence the popularity of dyed, dark brown mulches. However, gardeners should be concerned about using these dyed products, particularly as they may contain recycled pressure treated wood. In the future, the development of natural grass mulches made from darker-coloured straw species, such as big bluestem and Indiangrass, may prove helpful for expanding market demand for the ornamental grass mulch market. However, it should be recognized that the natural colour of

native grasses will fade in time as the water will leach the pigments from the grass. This will likely require gardeners to top-dress native grass mulch through the garden season. Another option is for gardeners to apply the warm-season grass mulch as their functional mulch and cover it with a dark coloured surface mulch for decorative purposes.

Figure 8. Big bluestem (L) and switchgrass (R) are the main native grasses of interest in Ontario for biomass production. Big bluestem dries down in the fall with a much darker pigment and may be more suitable for use as a darker coloured natural mulch for ornamental garden applications.

Table 1. Best Plant Applications for Warm Season Grass Mulch

Horticultural Crops	Berries	Gardens
Asparagus	Strawberries	Shrubs
Beans and Peas	Raspberries	Trees
Garlic	Blueberries	Perennial Flowers
Ginseng	Haskap	Perennial Herbs

How to Use Warm-Season Grass Mulch

As mentioned earlier, warm-season grass mulch can be used in a wide variety of horticultural and ornamental garden applications. Growers should adapt the use of the mulch to the growing system used for each crop. This section provides examples of how warm-season grass mulch can be used successfully in strawberries and ornamental prairie gardens.

Strawberries

Since 2008 in Quebec, switchgrass has been of considerable interest as a superior mulch in strawberry production. A main reason for this interest was that growers were looking to improve winter cover to increase strawberry winter survival. As well, they were looking for improved weed control and a reduction of cereal straws volunteering plants in strawberry fields. The use of switchgrass mulch for strawberries in Quebec is now becoming a popular practice among leading growers.

One promising system that has been developed is a just-in-time delivery of the switchgrass for fall mulching applications. Switchgrass is baled at approximately 30%–40% moisture in early October and then chopped to a long cut and blown over the berry crop in the field. The bales are shredded and applied to fields before any significant heating in the bales occurs. The grass will often be a yellow-green colour at the time of fall application. Switchgrass mulch provides better winter survival, as its structural strength is considerably greater than that of cereal straw. The warm-season grass mulch better protects the strawberries from low-temperature damage to the crowns and shallow roots. Protecting the crown is critical, as flower buds, leaves and runners all develop from the crown. An effective winter mulch will also help moderate soil temperature. When soil repeatedly freezes and thaws, it tends to push plants up and cause heaving. Uplifted plants are left in a state where they are much more vulnerable to desiccation.

Figure 9. On-farm trials in Quebec have tested cereal straw (top left) vs switchgrass straw (above) for 10 years. Switchgrass tends to provide better winter protection.

Cereal straw tends to flatten over winter, while switchgrass tends to maintain its form and resist snow load. Cereal straw is usually applied at a 10–15 cm thickness, which settles to 5–8 cm. Switchgrass tends to be less compressed by snow. It helps improve winter survival, as a thicker mulch layer is present to trap blowing snow during the winter. The rigid nature of the switchgrass also tends to help resist ice crust formation over the fields.

In the spring, most of the mulch cover is pulled into the alleyways by hand forking, to allow the strawberry plants to emerge faster. Switchgrass mulch will often tend to delay spring soil warming, so some removal of the material to the footpaths will help hasten the crops' spring emergence. Switchgrass mulch tends to stand up to foot traffic well. It is known to have greater fibre strength than cereal straws.

Another major advantage growers appreciate is that the mulch is slower to decompose. This provides more effective weed control and better protects berries. Switchgrass mulch also tends to have considerably fewer weed seed contaminants than cereal straws. This is particularly an advantage in the case of organic farms, which use organic straw, which is often contaminated with weed seeds. Cereal straws such as oats and barley are also notorious for self-seeding. This causes problems for growers, as the cereals create competition for moisture, nutrients and light with the strawberry plants. As well, the reseeding cereals are visually less attractive for Pick Your Own operations. Grower experience with switchgrass mulch to date is that switchgrass has limited amounts of self-seeding. For conventional strawberry growers, fields have been exceptionally free of grass weeds when using a grass herbicide in conjunction with the switchgrass mulch.

Figure 10. A main benefit of the switchgrass mulch is improved control of annual weeds for strawberry producers. Switchgrass straw contains fewer annual weed seeds and does not volunteer cereal grains. It also prevents emergence of annual weeds as it immobilizes surface soil nitrogen and shades the soil surface where small light dependent weeds germinate.

Some of the main advantages of switchgrass mulch on strawberries identified through extensive on-farm trials in Quebec include:

- improved winter hardiness, as switchgrass tends to be less compressed over winter by snow loads, compared to cereal straw
- improved weed control, as switchgrass lasts longer than straw and provides greater residual weed control, contains fewer annual weed seeds, appears to suppress the growth of annual weeds more effectively and immobilizes N at the soil surface
- better protection of berry tips touching the ground and being eaten by surface-dwelling insects, which results in less damaged fruit
- production of more mulch per hectare than cereal straw, depending on the soil productivity. Typically, switchgrass can produce 6–10 t/ha in most strawberry-growing areas, while cereal straw may produce 2–3 t/ha. The requirement of 4 tonnes/ha of straw, to be applied over the rows in a strawberry field, may be met from 0.5 ha of switchgrass.

The only minor disadvantage that has been identified with the use of switchgrass compared to cereal straw is that the material has a duller colour. Cereal straw tends to have a shinier golden hue that some growers have noted is more visually appealing for Pick Your Own operations.

In Ontario, on-farm trials are now being conducted to compare both switchgrass and miscanthus as straw mulches with commercial strawberry growers.

Figure 11. The switchgrass mulch has held up well to the end of the berry season. The slow to decay mulch provides effective residual weed control and helps prevent the tips of the strawberry from making contact with soil.

Mulch Use in Ornamental Flower Gardens

Switchgrass mulch can be used with great success in perennial flower gardens, as well as around shrubs, when the plants being mulched are not surface feeders and have deep root systems. The use of switchgrass mulch is ideal in these situations as it is highly favourable to plant growth and highly suppressive of annual weeds. Typically, the system can be managed with a once-a-year weeding, followed by a once-a-year application of well-chopped mulch applied to a ~3 cm depth in mid-May. Any weeds growing on the site can be removed with a hoe in spring, then the mulch can be immediately applied.

Figure 12. A prairie garden with switchgrass mulch emerging in the spring in mid-May. Approximately 40% of the switchgrass mulch will remain from the previous year. Once well established the garden will require limited spring weeding prior to re-application of new mulch. Late emerging plants such as butterfly weed and small first year plants can be marked with stakes the previous fall.

Typically, perennial flowers can be left to emerge to a 10-cm height before the weeding and mulching occur in May, so the plants are not covered with new mulch. As well, it is an ideal time to divide old plants for multiplication and to transplant new plants into the garden. To create a very simple system to manage the garden, native prairie garden plants can be chosen with an emphasis on the use of well-behaved species — species that tend not to spread through rhizome formation or spread excessively at the base. Plant species that have a spreading tendency are best contained in a plastic ring, such as a used plastic barrel cut into slices. All too often, mulched prairie gardens will be dominated by a single species (such as black-eyed Susan - *Rudbeckia hirta*) if gardeners do not plan well and manage the diverse species being planted. Gardeners may choose to plant tall species at the centre or back of the garden and shorter species at the front. Typical spacings for tall plants may be 60 cm while spacings for shorter plants may be approximately 45 cm.

A 2–3-cm length of chop on the mulch provides a most aesthetically appealing mulch that draws the eye to the plants as opposed to the mulch. Longer cuts of the mulch have a more unrefined look, and the material is more easily caught up in the vegetation when applied or spilled over onto the lawn. Well-conditioned warm-season grass mulch is soft and can be applied without gloves, whereas gardeners using woody mulches often wear gloves when applying the material, which they find less appealing.

Figure 13. The newly applied switchgrass mulch (bottom left) is 2-3cm long and creates a more aesthetically pleasing and functional mulch than the previous years long cut switchgrass straw mulch (bottom right).

The 2–3-cm chopped mulch surrounding the garden plants can present the plants very well. In certain types of gardens such as a prairie garden, the mulch is only visible for about 4–6 weeks per year, as the plants will completely fill in and occupy the garden space. Its main role is to suppress weeds and prevent the garden soil from overheating in the hot summer sun. In some areas, an established garden will completely eliminate the need for supplementary weeding and watering, effectively becoming a "do-nothing" garden.

Figure 14. A fine chopped mulch on a diverse and well spaced prairie garden in late May. The plants used for this type of prairie garden system must be reasonably well behaved (not moving with aggressive runners/rhizomes). When gardening with these natural warm season grass mulches, larger areas of beautiful healthy plants and shrubs can be grown with less work.

Newly planted plants in an existing garden should be marked with a small stake for the season and watered periodically during the summer. For most gardens, watering the new transplants is best done with a watering can. Excessively watering the mulch is not a good idea, as it will promote more rapid decomposition. Another advantage of the mulch is that it will capture rainfall or water applied through a hose during dry spells. Warm-season grass mulch is highly effective at infiltrating this water and at subsequently preventing evaporation of this moisture from the soil. Once fully established, mulched prairie gardens should need limited watering through the summer. In Ontario, it is likely that the garden may only require a few waterings to maintain the garden throughout the summer. Plants that prefer more mesic prairie conditions, such as culvers root or Ohio spiderwort, can be watered somewhat more frequently using a watering can.

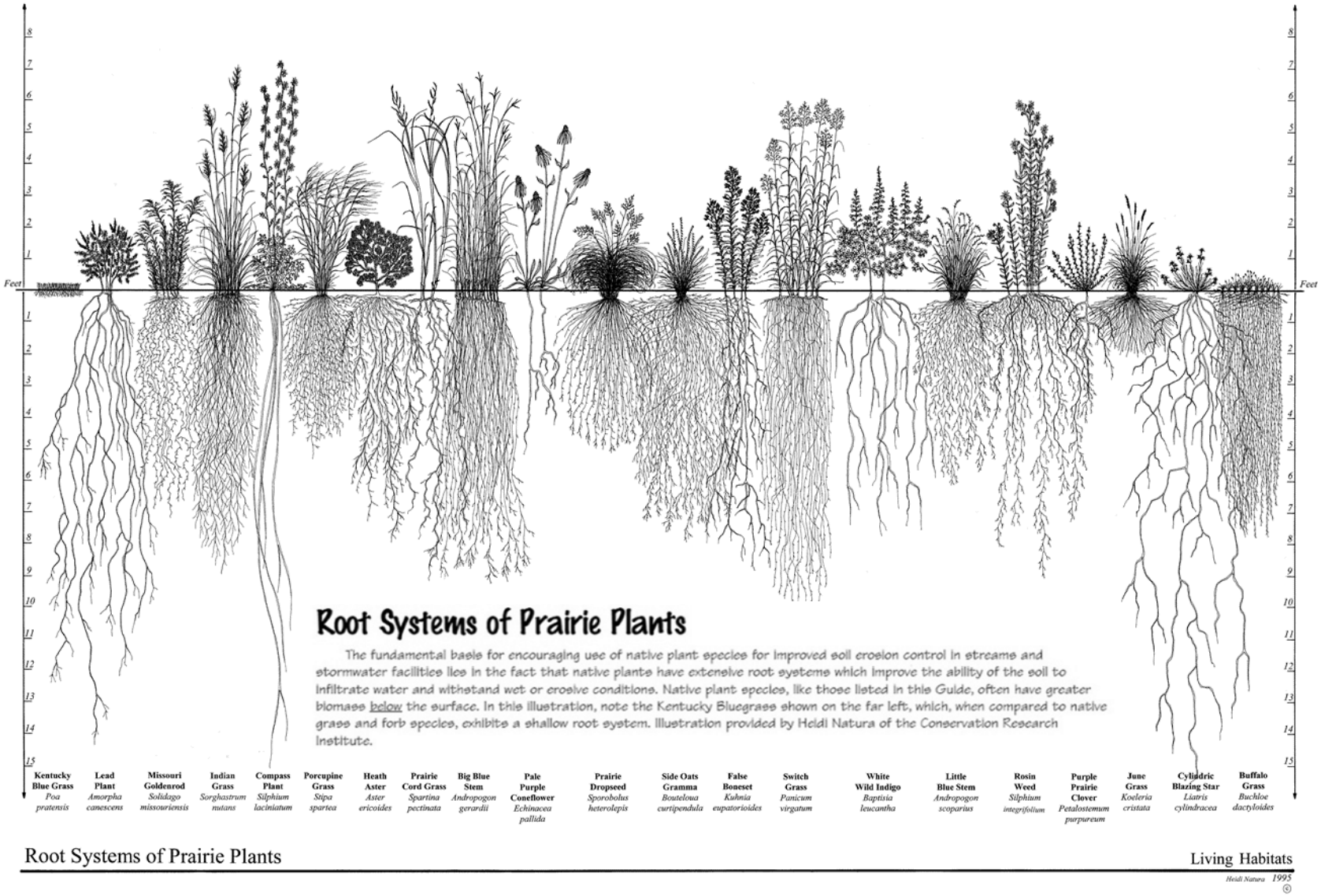

Figure 15. The deep rooting systems of prairie plants under a surface cover mulch of decomposing prairie grasses. Deep rooted prairie garden flowers are ideal for use with a switchgrass mulch garden system to develop a "do-nothing" system of gardening.

Figure 16. The author's diverse prairie garden has been mulched with a 2.5 cm long switchgrass mulch to create a "do-nothing" garden system. It brings colour to the home landscape without the need to use coloured wood mulch. The plant species that work well in this system include (butterflyweed (orange), anise hyssop (blue-purple), Ohio spiderwort (blue and white), culver's root (white), liatris spicata (purple), wild geranium, blue wild indigo (blue), echinacea purpurea (purple) and compass plant. Others that may need containment include wild bergamot, ox-eye sunflower(yellow), and cutleaf or greenheaded coneflower. Caution also with ox-eye sunflower as it tends to be a prolific self-seeder.

Figure 17 and Figure 18. A prairie garden with a diverse plant selection will draw in a diversity of wild pollinators. Warm season grass mulch makes it so much easier to manage these ecologically important native plants that can create a more colourful, visually stimulating and biologically interesting garden.

Summary

There is a growing interest by farmers in planting warm season grasses as soil building perennial crops. However, these grasses have considerably different attributes than cool season grasses that are commonly planted on ruminant livestock farms. Mulch is a promising market application for warm season grasses as it exploits their distinct attributes. It is the combination of the grass mulches having a high C to N ratio, low bulk density, high phytolith content and being thin stem walled which makes them ideally suited to both improving farm and garden plant production and soil building processes.

The main immediate functional benefits warm season grasses provide as a mulch cover over wood products are superior weed control, enhanced moisture conservation and no phytotoxicity (negative effects on plants). However, it is the long term soil building processes that are created through the decomposition of high carbon warm season grass mulch that is especially beneficial over woody mulches. Warm season grass mulches are exceptional in their ability to contribute to long term aggregate stability and soil organic matter formation. Growers are getting outstanding results from diverse mulch applications including use on vegetable crops and berries as well as ornamental shrubs, trees and perennial flower beds. With further research and grower experience warm season grass mulches appear to have a promising future as a sustainable farming and gardening strategy that conserves and enhances natural resources while providing optimal plant growth conditions.

Appendix

1. Sources of Switchgrass and Miscanthus Mulch:

Ontario Biomass Producer's Co-operative

www.ontariobiomass.com

Figure 20. Warm-season grass mulch is being sold and distributed by OBPC in both bulk and bags.

2. Sources of Switchgrass Seed and Miscanthus Rhizomes:

Ontario Biomass Producer's Co-operative

www.ontariobiomass.com

Ernst Conservation Seeds

www.ernstseed.com

Great Lakes Miscanthus

wwww.glmiscanthus.ca

Quality Seeds

www.quwww.qualityseeds.caalityseeds.ca

3. Sources of Additional Reading

Herms D., M. Gleason, J. Iles, D. Lewis, H. Hoitlink and J. Hartman. 2001. Using Mulches in Managed Landscapes. 12 pp.

https://store.extension.iastate.edu/Product/Using-Mulches-in-Managed-Landscapes-Sustainable-Urban-Landscapes

Robbins J. Plant Injury from "Sour" Wood Mulch. University of Agriculture Research and Extension. Publication FSA6138, 2pp.

https://www.uaex.edu/publications/PDF/FSA-6138.pdf

Samson, R.A., A. Arkinstall, and J. Quinn. 1992. Effect of winter rye mulches and fertilizer amendments on nutrient and weed dynamics in no-till soybeans. Soil and Water Environmental Enhancement Program (SWEEP) Report #57b, Agriculture Canada, Guelph, Ontario, May 1992. 32 pp.

http://agrienvarchive.ca/download/sweep_57b.pdf

Samson, R., E. Delaquis, B. Deen, J. DeBruyn and U. Eggimann. 2018. A Comprehensive Guide to Switchgrass Management. Ontario Biomass Producers Cooperative. 95 pp.

http://www.ontariobiomass.com/Agronomy-Guides-and-Grower-Info