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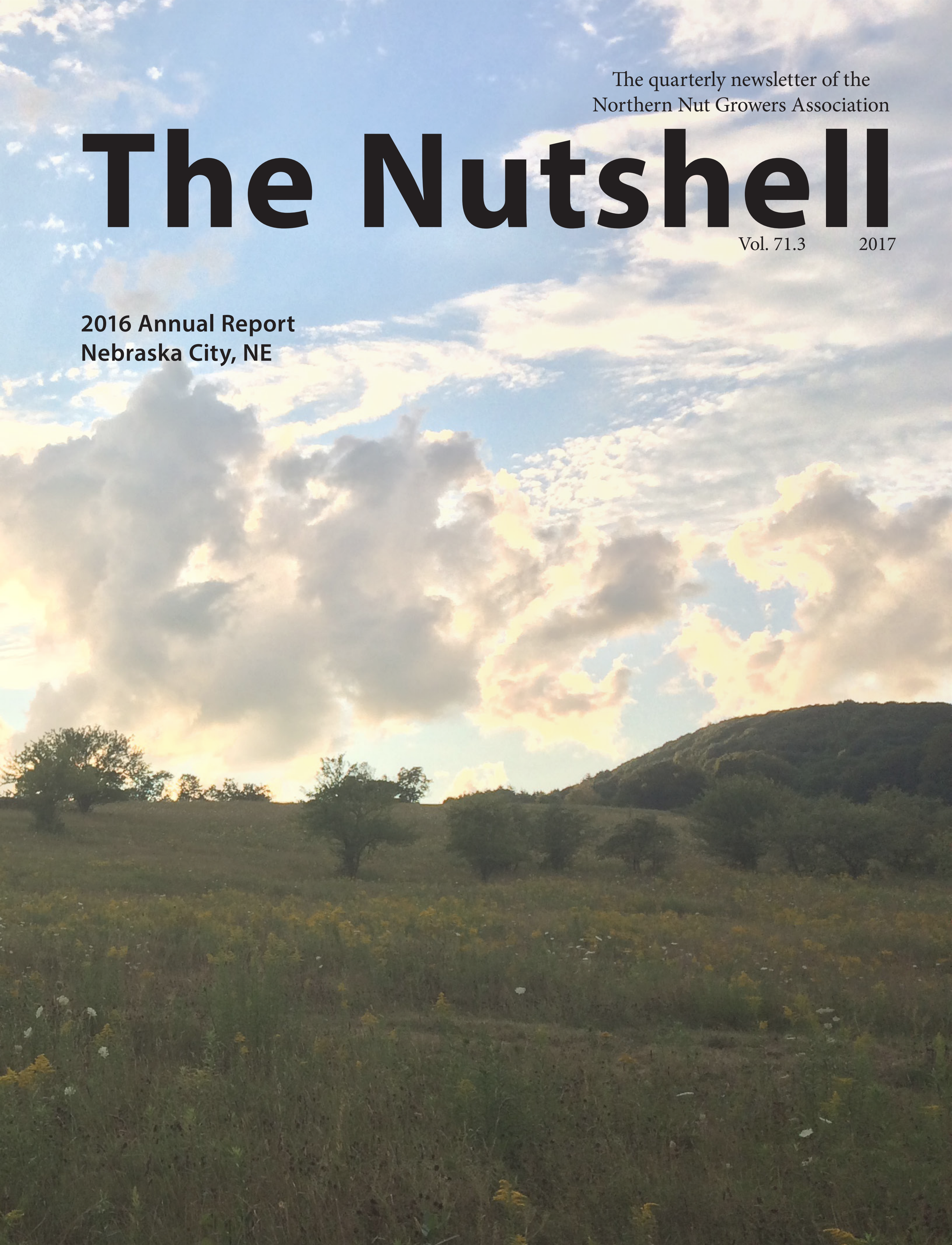

Orchard Management using Cover Crops to Improve Soil Health and Pollinator Habitat in the Midwestern United States

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National initiatives have emerged that could benefit future establishment and management of nut production orchards. The 2008 and 2014 Farm Bills put forward agendas to address declining soil health on agricultural soils by promoting the use of cover crops to improve soil health during the fallow period in rotation with agronomic crops. Corn, wheat, and soybean yields have been increased by 2 to 4 percent when grown in rotation with cover crops (SARE 2017). The USDA reported over 10 million acres were planted with cover crops in 2012 and has increased to over 20 million acres by 2017. Cover crops could play an even bigger role in managing soil health in orchards because we can include perennial ground covers and because annual cover crops, if not invasive, do not need to be terminated to establish another crop and can grow to maturity.

Declining populations of the honeybees and the monarch butterfly have brought national attention to the importance of pollinators and other beneficial insects. Over 100 agricultural crop species in North America, whose fruits and seeds provide over 30 percent of the food we consume, need a pollinator to achieve their full potential yield. It is easy to envision using certain cover crops in orchards that both improve soil health and aid in restoration of suitable habitats supporting pollinators and other beneficial insects.

BENEFITS OF USING COVER CROPS

Cover crops have grown in popularity over the last few years as growers have become increasingly aware of declines in soil health with current cropping practices. The four basic soil health principles are to (1) minimize disturbance, (2) keep the soil covered, (3) increase plant diversity, and (4) keep plants growing throughout the year to feed the soils. Following these four principles helps achieve soil health by minimizing soil erosion, maximizing organic matter storage, maximizing soil microbial populations and diversity, maximizing water infiltration, percolation, and retention in the soil, and minimizing compaction. The top five reasons farmers give for planting cover crops include increasing soil organic matter, reducing soil erosion, reducing soil compaction, managing weeds, and providing an alternative N source (Clark 2007). Other benefits include reducing fertilizer costs, increasing water infiltration and water holding capacity, sequestering nutrients that otherwise would leach into the subsoil, adding biological biodiversity to the cropping system, and providing an alternative source of income. Different plant species used as cover crops will vary in their ability to provide these benefits.

Cover crop suitability for orchards is summarized in Table 1 for 70 candidate cover crop species. Agronomic information for these cover crops is summarized in Table 2 including how, when, and where to plant them and their forage productivity and suitability. Although many other species could have been chosen, the final list was selected to include some of the most frequently used cover crops, some ground covers commonly found in orchards (both good and bad), and some promising native forbs for creating pollinator habitat.

One of the best indicators of soil health is the organic matter content. Organic matter is composed of dead plant and animal matter in various stages of decomposition. Without organic matter, soil is essentially a mixture of ground-up and weathered rocks. The importance of organic matter in managing soil moisture cannot be overemphasized as one pound of organic matter can absorb 18 to 20 pounds of water. Under intensive use of agronomic crops, organic matter in many soils has gradually declined from 4 to 6 percent to less than 2 percent. Use of cover crops is one of the more practical approaches to gradually increasing organic matter content (Table 1: Soil builder). Although plant tops provide organic matter, it is actually the extensive root systems that contributes the most to building organic matter and soil improvement.

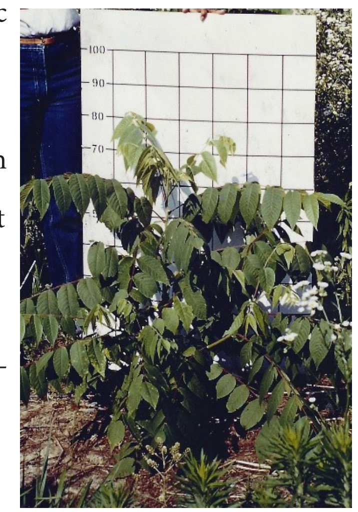
A second more easily observed indicator of good soil health in agricultural soils is the earthworm population (Fig. 1). A healthy soil can have over a million earthworms per acre or about two to three earthworms per shovel full.

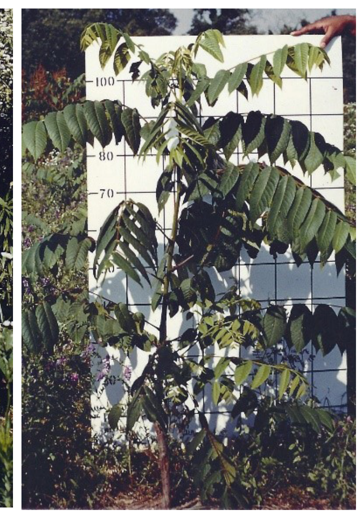
Plant residues left on the soil surface serve as a mulch or protective cover. They reduce the impact of raindrops associated with soil crusting and reduce the loss of soil by wind and/or water erosion (Table 1: Erosion preventer). In addition, a cover of vegetation and plant residues decreases the daily amplitude of changes in soil temperature and moderates seasonal fluctuations compared to bare soil. Lower soil temperatures in the summer are beneficial because they reduce the rate of microbial decomposition of organic matter. Slowly decomposing cover crop residues also provide a long-lasting mulch to control weeds and potentially act as a slow release fertilizer for the trees (Table 1: Weed suppresser and Table 1: Nitrogen source).

Cover crops can also be efficient nutrient scavengers. Cereal grains or grasses with fibrous root systems are good at scavenging excess fertilizer and nutrients especially nitrate-N, calcium, and potassium that might otherwise leach into the subsoil during a fallow period (Table 1: Nutrient scavenger). Grasses reportedly can take up more than 75% of the nitrate-N applied in water within 24 hours. Grains like winter wheat, cereal rye, and even oats, seeded in the fall can absorb within a three-month period more than 70 pounds of N per acre. This N is slowly made available the following spring if the cover crop winter kills or is terminated with cultivation or herbicides. Grass cover crops have been shown to reduce by 75 to 95 percent overwinter nitrate losses that occur from fallow fields.

Legumes go a step further than grasses because legumes have nodules on their roots containing bacteria that can take N from the air and fix it into forms that the plants can use in exchange for sugars from the plant. Some of that N can escape from living roots but most is slowly released as plant residues decompose. In the absence of other cover crops and weeds, this N can be taken up by trees and other plants (Van Sambeek, et al. 1986). Decaying biomass is expected to make 50% of the bound N available the first year, 30% the second year, and 10% the third year.

Nitrogen fixation rates can range annually from less than 50 to over 150 pounds of N per acre depending on the species (Table 1: Nitrogen source). The amount of N added





is highly depended on inoculating seed with the correct rhizobium, the amount of forage produced (Table 2: Productivity), and the crude protein content of that forage (Table 2: Crude protein). As a general rule, without N fertilization, most legumes fix 60 to 75% of the N needed for their growth with approximately 60 to 70% of their N in the aboveground forage. There should be little net loss or gain of available soil N in the orchard when haying legume cover crops. If not harvested, legumes should provide a net gain as plant residues decompose into available soil N that trees can take up (Fig. 2). Information difficult to find is which perennial legumes as they mature conserve fixed N and which slough off roots and nodules. High foliar N in walnut planted with crownvetch would indicate fine roots and nodules are sloughed off in the dormant period during the summer. If fertilizer is added to the cover crop when orchards are fertilized, the legumes will utilize the available soil N and be less likely to form nodules that fix atmospheric N.

Cover crops also provide other soil-related benefits. Biological activity in the soil is greatest if a ground cover with living roots is continuously maintained without a fallow period. A noticeable increase in biological activity in the soil can be seen within 2 to 3 weeks after cover crops begin growing. More than 80% of plants form symbiotic relationships on their roots with endo- or ecto-mycorrhizal fungi. These fungi make soil nutrients more available to plant roots. In addition, mycorrhizae produce glomalin, a sticky water-insoluble glycoprotein that binds soil particles together to form the stable soil aggregates needed to improve soil tilth (Table 1: Soil builder). The resulting pore space between aggregates provides an improved avenue for soil gas exchange, water holding capacity, and root penetration (Table 1: Topsoil loosener).

The upper roots of cover crops physically hold soil particles in place during storm events reducing sheet, rill, and gulley erosion. Estimates suggest it takes approximately 100 years to replace 1 inch of topsoil lost to erosion. Planting cover crops in tilled soil can reduce soil erosion by as much as 50 percent while no-till seeding of cover crops sometimes reduces erosion by 90 percent. Plants with deep roots may also penetrate compacted soil layers (Table 1: Rooting depth) improving soil permeability by producing channels and macropores that can be utilized by the tree roots (Table 1: Subsoil loosening). Cover crops that can loosen the subsoil can also capture nutrients and return them to the topsoil (Table 1: Nutrient scavenger).

Cover crops assist with controlling weeds by shading the soil, by rapid growth out competing the weeds, and/or producing phytotoxic compounds. Erect cover crops typically need to produce more than 3 tons per acre of biomass to suppress weeds while prostrate (white clover), semi-erect (cowpeas), and climbing (hairy vetch) plants require less biomass to be effective (Fig. 3). Productivity is also important because on average, 4 to 4.5 inches of precipitation are needed for each ton of forage (Table 2: Productivity) produced substantially diminishing the amount of soil moisture available to the trees. Some cover crops like cowpeas, millet, and medics use less water per ton of biomass than heavy users like alfalfa and cereal rye (Table 2: Water use).

Cover crops especially those with very rapid growth quickly shade the soil and change the ratio of red to far-red light reaching weed seeds near the soil surface so seeds continue to remain dormant (Table 2: Establishment rate). A few cover crops produce phytotoxic chemicals that can chemically inhibit seed germination and seedling growth of other plants (Table 1: Known allelopath). Cereal rye and to a lesser extent the other cereal grains release toxic compounds as plant residues decompose that can slow the growth of other plants. Decomposing residues of rapeseed, mustards, radishes, and other Brassica species act as biofumigants if tilled into the soil and can help manage soil borne-pathogens and nematodes that feed on plant roots. The ARS Cover Crop Chart suggests most annual species should not be planted back to back.

There are conflicting opinions whether single species or multi-species cover crops are better. Cover crops benefits are usually most closely related to the amount of biomass produced. Single species cover crops tend to produce more biomass per acre than will a mix of species. Penn State University published the results of a two-year study suggesting multi-species mixes, however, are more likely to provide a wider range of benefits (Finney and Kay 2016). Their results suggest mixtures of up to eight species are likely to produce more rapid changes in soil health and expected benefits of using cover crops than single species. Another plus is cover crop mixes are more likely to contain species adapted to the soil, although multi-species covers are more difficult to seed and establish due to different planting times, seed sowing depth, and growth rates (Table 2: multiple columns). The seeding rates shown in Table 2 are are rates to quickly establish a single species, dense stand using the lower rates if drilled in and the higher rates if broadcast seeded (Table 2: Seeding rates). In tree plantings rates can potentially be reduced by as much as 50 percent and still be effective. For multi-species covers, seeding rates are usually adjusted proportionately to desired final composition.

The USDA Natural Resource Conservation Service (NRCS) is actively researching the benefits of using cover crops to improve soil health. For example, the NRCS Plant Materials Center in Elsberry, MO has established demonstration sites for three years to measure the impact of fall planting date (late July to late September) on biomass production on more than 30 cover crop species alone or in mixtures. In general, cover crops seeded in August (6 to 9 weeks before first killing frost) produced the greatest above-ground fall biomass. Numerous technical reports have been published on the NRCS state and national websites which I have heavily utilized to write this article.

COVER CROPS AND NUT ORCHARDS

Nut orchards are usually not established on our most productive agricultural lands. As a result, these orchards should respond positively to use of annual or perennial cover crops. Integrating cover crops into an orchard operation can have some unique challenges as well as benefits not found when using cover crops in the normal fallow period between cash crops. Studies show having a ground cover can reduce hardwood tree growth anywhere from a few percent to more than 70 percent (Van Sambeek and Garrett 2004). It is important to recognize that the degree to which cover crops compete with the trees varies substantially. A few cover crops result in less than a 20 percent reduction in tree growth compared to other cover crops, such as tall fescue, that can result in more than a 50 percent reduction in tree growth (Table 1: Compatibility). Tall fescue, one of the easiest grasses to establish and manage, on average reduces walnut growth by nearly 70 percent (Fig. 4). This means if it takes 3 years to put on one inch of diameter growth in a weed-free planting, it will take more than 9 years if growing in a tall fescue sod. Data is not available on how long (if ever!) it will take for walnut trees in a tall fescue sod to start bearing harvestable numbers of nuts.

There appears to be a trend for deeper rooting of the cover crop to reduce compatibility (Table 1: Rooting depth) and a trend for annual cover crops to be more compatible than perennial cover crops (Table 1: Forb type), but not whether they grow as winter annuals or grow during the cool-season or warm-season of the year (Table 1: Growing season). Somewhat surprising there does not appear to be a strong relationship between cover crop compatibility and biomass productivity (Table 2: Productivity), production of phytotoxic compounds (Table 1: Known allelopath), or N-fixation rates among the legumes (Table 1: Nitrogen source). Table 1 does not include annual grasses such as soft chess, annual fescue, or cheat grown in the west which ought to be highly compatible with hardwood trees. These grasses are short, drought tolerant, self-reseeding winter annuals that mature very early in the spring and tolerate repeat mowing.

The amount of sunlight available to the cover crop in an orchard depends on row orientation, tree size, and tree density. In a nut orchard with open-canopy trees (branches not touching), sunlight can be reduced by 50 (moderate shade) to 80 (dense shade) percent. Studies conducted by University of Missouri Center for Agroforestry (UMCA) growing forages under moderate to dense shade show some cover crops such as Kentucky bluegrass, sweet clover, white and red clover have better growth under moderate shade than under full sun while other cover crops such as field peas and oats do poorly under moderate shade (Table 1: Shade tolerance). Most warm-season grasses exhibit little shade tolerance; however, eastern gamagrass may be an exception (Fig. 5).

Tillage in an orchard is usually discouraged to minimized damage to tree roots; however, it should also be discouraged to maintain soil health. Deep tillage for site preparation to seed a crop or for incorporating green manure crops is discouraged as it leads to more rapid turnover of organic matter, loss of N through volatilization and leaching, and breaking down soil structure or soil tilth. When surveyed, most growers indicated they establish cover crops by lightly incorporating after broadcasting seed or drilling in the seed. It may require several years of no-till following continuous tillage before improvements in soil health and crop productivity are observed. One source I found estimated it takes 7 to 9 years of no till to restore soil health and soil structure; however, cover crops can jump start the process reducing the time to 2 to 4 years because live roots are continually present supporting a diversity of soil microbes. If tillage is necessary, consider conservation tillage using equipment, i.e. chisel plows, which minimally disturbs the soil and leaves 30% or more of the soil covered by plant residues to minimize water and wind erosion. An early publication on no-till reported that earthworms alone can move more soil in a year than annual tillage with a moldboard plow.

In an orchard, cover crop options increase because perennial ground covers can be established and maintained. A continuous plant cover moderates soil temperatures compared to exposed soil. For walnut growing in grass sods compared to cultivated orchards, average spring soil temperatures are lower and can delay bud burst and flowering by 4 to 5 days so new growth is less susceptible to late spring frosts. Perennial cool-season cover crops should be left to flower, produce seed (unless the cover crop is invasive), and then go dormant over the summer to help conserve soil moisture. Summer mowing is discouraged because it can stimulate regrowth, especially on grasses, and renewed competition to the trees for available soil moisture and nutrients.

An added value of using forage cover crops in an orchard maybe the production of high quality hay for livestock (Fig. 6). When grown under moderate to dense shade, most plants produce less biomass with a higher quality forage (higher crude protein and less non-digestible fiber). Some cover crops like field peas and sorghum x sudan grass are better suited for harvesting as forage crops (Table 2: Forage value) while others like ryegrass, oats, and turnips are better suited for grazing (Table 2: Grazing value). Some cover crops should be grazed with caution because they can result in bloating, nitrate poisoning, or contain toxic compounds (Table 2: Toxicity issues). Apparently, the plants to be most concerned about are the vetches and some peas because of toxins present in the seeds when the plant matures.

In addition to improved performance of the animals, benefits of grazing an orchard can include pasture rent and reduced costs for mowing. Also in some cases, the value of a cover crop on soil health can be increased by grazing. Benefits from grazing, however, need to be weighed against additional costs for fencing and fertilizer. In grazed pecan orchards, fertilizer rates for N and K should be increased by 30 and 20 pounds per acre, respectively. Animal wastes, i.e., urine and manure, are not a substantial source of N as approximately half the N is volatilized as ammonia back into the atmosphere.

When grazing an orchard, follow the UMCA silvopastoral guidelines to minimize compaction and overgrazing (Fig 7). Their guidelines suggest creating multiple small paddocks so livestock can be rotated when forage cover is reduced by two-thirds or plants grazed early in the rotation show new growth. To minimize compaction in the orchard, maintain some open pasture, so livestock can be removed from the orchard when soil moisture is near field capacity (Jose, et al. 2017). Cattle should be removed from an orchard about a month before nut harvest to minimize contamination of nuts by dry manure during harvesting.

When choosing a cover crop consider how plant residues will impact the harvesting operation. Plants with tall woody stems will make it difficult to pick up the nuts even if mowed (Table 2: Mature height). Also most mechanical harvesters are not designed to handle the large volume of biomass produced by many cover crops (Table 2: Productivity). Another consideration, especially for perennial cover crops, is how well they will recover from late fall mowing or harvesting when preparing the orchard floor for nut harvesting (Table 1: Mowing tolerance). Although Daikon tillage radish can be used to break up the plow pan found under many orchards, it is easily pulled up by mechanical nut harvesters, jamming the machinery and leaving holes on the soil surface.

When cover crops are planted into black walnut plantings and to a lesser extent in pecan and hickory plantings, some consideration should be given to the susceptibility of the cover crop to juglone produced by these trees. Numerous lists exist as to what plants are supposedly tolerant and susceptible to juglone (Table 1: Juglone toxicity). It is important to note that by improving soil health, i.e. increasing the organic matter and microbial populations and diversity, we lessen the likelihood of juglone toxicity occurring. The most likely explanation for the contradictions found among the lists of susceptible and tolerant plants likely has to do with differences in the biological activity of a soil. Soils high in organic matter, diverse populations of microbes, and good aeration are unlikely to show toxicity from juglone.

Pecan and to a lesser extent walnut are likely to be planted on sites subject to flooding. Grass cover crops are more likely to survive extended periods of flooding than legumes or other cover crops. There is considerable variation in sensitivity to flooding within in both the grasses and legumes (Table 1: Flood Tolerance). Alsike clover and redtop are two of the more flood tolerant perennial cover crops.

Integrating cover crops into an orchard can create some unique problems (Olcott-Reid and Reid 2007). Because legumes, especially the clovers, aggressively take up P, K, and zinc, orchards may require broadcast application of PK fertilizers and foliar application of zinc. Clover and hairy vetch plots are attractive to deer and seem to increase browsing and buck rub problems. Cover crops are also likely to increase the mice and vole populations followed by increased population of snakes. Pecan growers may not want to mow or harvest the cover crop from August 1 until shuck split to lessen movement of stink bugs into the trees.

In *Managing Cover Crops Profitably*, Clark (2007) says there is a cover crop to fit just about every situation and suggests starting by considering the top cover crops species recommended for the Midwestern US. These are marked with an * in Table 1 and 2. Clark included an example for a sloping orchard needing a cover crop to control erosion, contribute organic matter and N, attract beneficial organisms, limit rodents and other pests, conserve soil moisture, and

leave soil nutrients available during key periods of nut development. He recommends selecting a cover crop that does not produce too much N causing excessive leaf growth, can be a perennial or reseeding annual, is low growing and needs minimal management, uses water efficiently, releases nutrients during the growing season, and harbors or attracts few pests. After considering more than 30 options, Clark suggested using white clover or possibly strawberry clover (although they attract pocket gophers) mixed with quick-growing reseeding soft brome or annual ryegrass even though these grasses will likely require periodic mowing. As alternatives, Clark suggests using reseeding winter annuals such as crimson clover, subclover, one of the vetches, or an annual medick.

COVER CROPS AND POLLINATORS

Along with improving soil health, cover crops also offer some options for restoration of suitable habitats that support pollinators and other beneficial insects. The 2008 and 2014 Farm Bills contain specific language that make pollinators a priority of USDA conservation programs and calls for enhancement or restoration of millions of acres for pollinator habitat. Under the 'National Strategy to Promote the Health of Honey Bees and Other Pollinators,' almost 200,000 acres were signed up for planting to a mix of forbs to provide nectar, pollen, and nesting sites. It is estimated that approximately 120 crops benefit from pollination by native and honeybees with an estimated 3 billion dollars annual contribution to the US economy.

Besides the introduced European honeybee, there are close to 4,000 other mostly native bee species and 40 bumblebee species found in the US (Fig. 8). About 70 percent of the native bee species reproduce in tunnels in the soil. Most are solitary with each female locating and provisioning her own nest with pollen before laying eggs. Roughly 30 percent of native bees nest in woody materials which can include dead wood or plants with pithy stems. Bee species are attracted to different kinds of flowers depending on their color, structure, and size (Table 1: Bee forage value).

Adding cover crops to an orchard will increase the abundance and diversity of insects. In addition to bees, cover crops should increase the abundance of other pollinators including other insects such as butterflies, moths, and some beetles and the diversity and abundance of beneficial insects such as predatory lady beetles, lacewings, hover flies, and parasitic wasps. These insects also need pollen and nectar sources during part of their life cycle. Preferred flower colors include purple, violet, yellow, white, blue, and red although honeybees apparently cannot detect red. Managing for predatory and parasitic insects should mean the presence of fewer destructive insects including aphids, slugs, caterpillars, and grasshoppers. UMCA studies have shown that the number and diversity of predatory and parasitic insects is greater in a walnut alley-cropping practice than in pure alfalfa stands (Stamps, et al. 2009). The value of different cover crops for pollinators (excluding bees) and beneficial insects is summarized in Table 1 (Table 1: Beneficial insects).

Trees and shrubs can provide significant forage (pollen and/or nectar) for native bees although walnut, pecan, and chestnut are not usually listed. These nut trees, however, add value by making it easier for pollinators to fly and visit flowers as well as serve as buffers to drifting pesticides. Honeybees stop pollinating when it gets too windy and prefer to forage on the lee side of trees. Increases in pollination efficiencies can extend out into the orchard 10 to 15 times the height of the trees.

Legumes are excellent sources of pollen and nectar for pollinators and beneficial insects in addition to being able as cover crops to boost soil fertility. Wells (2017) reports that planting legumes in pecan orchards can build-up populations of beneficial insects. When the cover crop dies or goes dormant, the beneficial insects are driven up into the trees and feed on pecan insect pests. Recognize that reaching maturity or death of the clover is also likely to drive insect pests into the tree canopies such as stink bugs that feed on the immature nuts. Although grass cover crops do not provide nectar, they can provide pollen and be an important host for some caterpillars. Grass pollen is marginally attractive to bees because it has a lower protein content than the pollen of broadleaf plants.

It is important when managing for pollinators to use a mix of species to assure flowers are present throughout most of the growing season (Table 1: Bloom period). Preference should be given to species with long flowering periods. The NRCS recommends a mix of at least 10 species with one bunch grass or sedge species and a minimum of 3 species flowering during the spring (March-May), summer (June-August), and fall (September-November). They suggest managing for at least one plant species (could be a weed if not noxious or invasive) that flowers very early as food source for pollinators emerging from hibernation and one species that flowers very late as a food source as pollinators go into winter dormancy. NRCS emphasis is on using native wildflowers or forages because they are less likely to become invasive (Table 1: Can be invasive) and because of their tolerance for lower fertility soils and lower water use per ton of biomass. Also, native wildflowers seldom require use of pesticides.

In a nut-producing orchard, cover crops should be chosen that will not be in flower when insecticides are to be applied to control insects such as the pecan weevil. Alternatively, managers could mow the cover crop or spray half or less of the area at a time so insects can leave the area or have time to move back into the treated areas, respectively. Other options are to spray early in the morning or late in the evening when bees are least active and when insecticides are less likely to volatilize or drift. When possible, avoid the use of systemic insecticides which are absorbed and move through the plant injuring both the target pest as well as pollinators and beneficial insects foraging pollen and nectar. The systemic neonicotinoid insecticides are especially harmful because they can persist in the environment and be taken up years later by other plants attractive to pollinators.

An easy second option for restoration of pollinator habitat is to establish permanent native wildflower strips in the orchard within the tree rows or wider strips along the borders and fence rows (Fig. 9). The NRCS recommends strips 30 feet wide along field borders to facilitate periodic mowing or patch burning needed to maintain plant diversity. If strips include wildflowers and grasses, use bunch grasses like orchard grass or little bluestem. Permanent wildflower strips provide undisturbed areas for ground nesting bees to excavate their underground tunnels along with a temporary source of pollen and nectar through the growing season when cover crops are not flowering.

Cover crops and forbs of high value to pollinators and beneficial insects include annuals such as buckwheat, hairy vetch, rapeseed, crimson clover, phacelia, sunn hemp, and sunflowers; biennials such as partridge pea, sweet clover, forage radish, and turnips; and perennials such as alfalfa, kura clover, white clover, red clover, sainfoin, and the tick trefoils (Table 1: Bee forage value and Table 1: Beneficial insect value). Many of these same plant species also provide important benefits for improving soil health as N sources (Fig. 10).

Buckwheat is one of the best cover crops for attracting bees and beneficial insects. It grows rapidly, smothering other weeds, and is easily killed by mowing when seed is still immature so it does not become invasive.

Partridge pea is an especially promising native prairie plant for establishing between trees leaving alleys within the orchard available for agronomic or low growing cover crops. It can fix its own N, has a relatively long blooming period, attracts pollinators to both the flowers and extra-floral nectaries at the base of the leaves, and has weak stems that can cover and smother other weeds.

Another species to consider adding to any permanent wildflower strip or border are native milkweeds although they are considered to be unpalatable by livestock. Milkweeds are the sole source of food for caterpillars of the monarch butterfly and support a wide range of pollinators with abundant high-quality nectar and pollen. Missouri has 18 species of milkweed that are adapted to a range of soil conditions, so one or more species should be adapted to our orchard soils. Common milkweed may be the easiest to establish because it is the only milkweed that occurs naturally in cultivated fields.

A third option for improving pollinator habitat is interplanting flowering shrubs and small trees within the rows between the nut trees. In addition to being sources of pollen and nectar, they can also be a source of additional revenue to the orchard manager if the fruit is harvested. Most can be pruned to single stems and allow for mechanical nut harvesting. The list of native woody species in the Midwest includes a few legume or actinorhizal shrubs capable of fixing atmospheric N. None of the native woody species I have tried added sufficient N to change foliar N levels in intercropped pecan, so it unlikely native woody N-fixers can improve nut production although I did not measure nut production.

If soils are not well drained and are low in organic matter, shrubs will need to be selected that tolerate the accumulation of juglone in black walnut orchards. Pollinator-friendly species tolerant of juglone and their bloom times include witch hazel (Jan-Mar), hazelnuts (Mar-Apr), redbud (Mar-Apr), service berry (Mar-Apr), plums (Mar-May), peaches (Mar-May), pecan (Apr-May), persimmon

(Apr-May), nine-bark (Apr-May), raspberries (Apr-Jun), cherries (Mar-May), pawpaw (Apr-May), sassafras (Mar-May), elderberry (May-Jul), lilac (May), and willow (Apr-May). Because of their sensitivity to juglone, apples (Mar-May), blueberries (Apr-May), grapes, blackberries (Apr-Jun), or basswood (May-June) may not be good choices in a black walnut orchard.

SOURCES FOR ASSISTANCE

Adding cover crops into a farming or orchard operations is estimated to cost between $20 and $50 per acre per year. With a little creative thinking, orchard managers can take advantage of several government programs to offset costs associated with use of cover crops and creating pollinator habitat. Under the Conservation Reserve Program, the USDA Farm Service Agency plans to enroll nearly 270,000 acres of private lands in a special pollinator-specific initiative. The Monarch Butterfly Habitat Development Project and the Environmental Quality Incentives Program (EQIP) both funded by the USDA-NRCS will provide cost-share funding to landowners to carry out management practices that include both using cover crops and establishment and improvement of pollinator and butterfly habitat.

When current growers of cover crops were asked where they purchase their seed, most listed companies specializing in cover crop seeds, followed by agricultural retailers, and then commodity seed dealers. Seed of the most agronomic crops like wheat, cereal rye, oats, soybeans, clovers, and ryegrass can usually be purchased from a local farm supplier. Some of these species have been bred to improve their performance as a cover crop such as Fixation balansa clover, AC Greenfix chickling vetch, or grazing corn and are available only from companies that specialize in cover crop seed. I obtained valuable information for this paper from the following companies that specialize in cover crops. Center Seeds (Minster, OH; http://www.centerseeds.com) is a nationwide distributor of only cover crop seeds with a network of dealers located throughout the Midwest. Green Cover Seed (Bladen, NE; http://greencoverseed.com) specializes in designing custom seed mixes to match grower's goals, planting dates, and locations. A search on the internet produces a list of other dealers that also offer seed for most of the species listed in Table 1. Most of these dealers have prepared mixtures or can do custom mixes designed to address specific soil or grazing needs. Some websites also have decision tools to aid in creating specialized mixes. Whatever dealer you decide to use, be sure to purchase the appropriate seed inoculum(s) for the legumes in the mix. Some companies are featuring an inoculum with a broad mix of rhizobial strains suitable for nearly all the legume cover crops. If possible purchase inoculums that also contain a mix of mycorrhizae to increase the effectiveness of rhizobial strains and aid non-leguminous plants in taking up available soil nutrients.

In closing, I want to acknowledge the contribution of numerous growers who have asked questions, discussed these ideas, and pushed me to develop this paper over the last 40 years. Finally, I wish to express my appreciation to Steve Shifley, Doug Wallace, John Kabrick, Nadia Navarrete-Tindall, Jerry Henkin, and Gina Zimbardi for their technical comments and reassuring me the information will be useful to those interested managing nut orchards and integrating nut trees into different agroforestry practices.

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EXPLANATIONS FOR VALUES IN TABLES

Table 1 compiles information for 70 of the most common cover crops or ground covers that could be planted in an orchard either as single species or part of a mix to form a living mulch. This table lists growth characteristics, tolerance to stressors, suitability as cover crops and value to pollinators and other beneficial insects. Blank cells means insufficient information was found in the literature I reviewed for me to make even an educated guess. An orchard manager must decide which species will work best toward meeting their goals for producing nuts, alternative income, improving soil health, and creating pollinator habitat.

Column 1 (Species) gives a frequently used common name although many of these species go by multiple common names. Column 2 (Forb type) indicates whether the species is an annual (A), biennial (B), or perennial (P); and whether the species is a grass (G), legume (L), or a non-legume, broad-leaved forb (B). Column 3 (Growing season) indicates if the species is normally grown as a winter annual (WA), a cool season (CS), or a warm season (WS) forb.

Column 4 (Compatibility) is one of the more important columns for orchard managers as it indicates how likely a cover crop will be to decrease tree growth when compared to trees grown in orchards without a ground cover where A = less than 20%, B = 20-30%, C = 30-40%, D = 40-50%, and F = more than a 50% reduction in tree growth.

The next seven columns rate each species as to tolerance to various stressors. Shade tolerance indicates the reduction in biomass produced under moderate shade in an open productive orchard compared to biomass produced in open fields where A = less than 20%, B = 20-40%, C = 40-60%, D = 60-80%, and F = more than 80% reduction in biomass. Flood tolerance values rate the plants as to their ability to survive partial inundation where A = more than 3 weeks, B =1 to 3 weeks, C = up to a week, D = for a few days, and F = listed as intolerant of flooding. The next two columns give values for the plants ability to tolerate drought and low fertility soils on a scale of A = excellent, B = very good, C = good, D=fair, and F= poor. Mowing tolerance rates each species on the same scale as to how well they tolerate (recover) fall mowing prior to nut harvest (September for Chinese chestnut, October for walnut, and November for pecan). Juglone tolerance rates species as to whether the cover crop is listed as tolerant (T), susceptible (S), or results are mixed (M). The twelfth column (Known allelopath) indicates whether these plants produce chemicals that can slow the growth of other plants and potentially trees as Y = yes and N = not reported to be allelopathic to other plants.

Column 13 lists an average maximum rooting depth on deep soils. Most grasses have shallow dense fibrous root systems and compete more vigorously for soil water and nutrients than do most broad-leaved plants that tend to have taproots with less fibrous root systems.

Columns 14 to 20 describe the value of each species as a cover crop. As nitrogen sources, an A means plants can fix more than 150 pounds, B = 100-150 pounds, C = 50-100 pounds, D = less than 50 pounds actual N per acre, and F = a non-nitrogen-fixing cover crop. Values as a nutrient scavenger, soil builder, subsoiler, topsoil loosener, erosion preventer, and weed suppressor are rated as A = excellent, B = very good, C = good, D = fair, and F= poor based primarily on values assigned by Clark (2007), the Midwest Cover Crop Council (MCCC 2014), and my knowledge of the species. Column 21 (Can be invasive) indicates if a species can become invasive (Y = yes) and should be terminated before they produce mature seed unless we want it to reseed itself in future years.

Column 22 (Pollinator value) and column 23 (Beneficial insects) indicates the value of flowers as pollen and nectar sources to bees and the value of pollen, nectar, and forage to other beneficial insects including butterflies, moths, predatory, and parasitic insects from A (excellent) to F (very poor). Bloom period is the time interval when the species is in flower. Most plants flower heavily in the first or second month of the reported ranges but will flower over a longer period if mowed or grazed. The last column list how far north a plant will survive overwinter based on the plant hardiness zone maps (http://planthardiness.ars.usda.gov/PHZMWeb/Default.aspx).

Table 2 provides agronomic information to aid in establishing 70 cover crop species (column 1) listed in the same order as in Table 1. Blank cells means insufficient information was found in the literature I reviewed for me to make even an educated guess. Column 2 (Plant architecture) describes if stems are primarily erect (E), semi-erect (SE), prostrate (P) or climbing vines (V). Column 3 (Mature height) describes how tall the plant is normally when flowering. Column 4 (Acceptable soil pH range) gives average ranges found in the literature; however, if range is below pH 6 for legumes, they may be able to grow but will show little N-fixation. Column 5 (Times to seed in the Midwest) gives the appropriate seasons to seed in plant hardiness zones 5 and 6 and is shown as early (E) or (L) spring (Sp), summer (Su), fall (F), or winter (W). Column 6 (Fall seed) indicates when to seed in the fall for maximum cover crop benefits as the number of weeks before first fall frost (approximately mid-October in Missouri). Column 7 (Soil temperature) provides information on either the minimum soil temperature for germination or optimum soil temperature for rapid germination. Column 8 (Seeding rate) lists averages of low and high rates found in the literature for establishing a pure stand with the lower rates recommend if seed is drilled or incorporated and the higher rates if broadcast over disturbed soil. Column 9 (Sowing depth) indicates how deep seed should be drilled or incorporated (generally 2 to 4 times the diameter of the seed) into the soil which is heavily dependent on soil type, soil moisture, and seed size. Column 10 (Days to emerge) provides the average number of days before seedlings emerge from the soil if planted at recommended depth (column 11) and soil temperatures (column 9). Column 13 (Establishment rate) assigns values from A = very rapid and excellent for weed suppression to F = slow taking more than one growing season and normally established with a rapidly growing smother crop for weed control. Column 14 (Growth rate) assigns values from A = very rapid once initiated and excellent for weed suppression to F = slow and may require management of other vegetation if it is to survive. Column 15 (Moisture use) assigns values of how efficiently the cover crop uses soil moisture to produce a ton of biomass ranging A (less than 3" of precipitation) to F (over 4" precipitation per ton of forage produced). Column 16 (Productivity) provides expected cumulative forage yields in air-dried tons per acre if harvested one or more times at early to mid-bloom. Annual forage yields and water use can be substantially less for some crops if not harvested and left to mature. Column 17 (% Crude protein) provides an average percentage for crude protein in forages harvested for hay around early flowering. The product of crude protein times productivity gives an estimate of potential input of N into the soil as forages decompose (N-fixation in legumes normally stops at early flowering). Column 18 (Forage value) and Column 19 (Grazing value) indicate value from A (excellent) to F (very poor) for each species to livestock if harvested for hay or grazed, respectively. Column 20 (Toxicity issues) indicate if precautions must be taken to prevent bloat (B) or nitrate poisoning (N) when grazing, to prevent poisoning from cyanide or prussic acid (P) in improperly cured hay, or to prevent poisoning from toxic chemicals (T) present in the forage or seeds or chemicals created with improper drying of the forage.

FIGURE LEGENDS

Figure 1. Abundant populations of earthworms are an easily observed indicator of a healthy agricultural soil.

Figure 2. Walnut seedlings in second year of growth with weed control using only chemicals (left) or only a hairy vetch living mulch without chemical weed control (right).

Figure 3. Excellent cover of hairy vetch, an excellent nitrogen fixer, in a black walnut orchard that will suppress weeds and slowly release N as forage decomposes.

Figure 4. Twenty-year-old walnuts on an excellent site with very poor growth in response to the tall fescue ground cover that invaded the planting.

Figure 5. Eastern gamagrass, a shade-tolerant warm season grass, growing within a black walnut alley-cropping practice.

Figure 6. High quality eastern gamagrass hay harvested from a pecan orchard.

Figure 7. Feeder cattle have grazed down the grass cover crop in a pecan orchard and are ready to be moved to a new paddock.

Figure 8. One of almost 4,000 species of bees that can be found foraging for nectar and pollen in the US.

Figure 9. Photo of a five-year old native wildflower border with minimal management taken in July that was seeded without native grasses.

Figure 10. Excellent stand of Kura clover established in a young pecan orchard as an N source, for weed suppression, and for hay.

Table 1.—Traits of possible cover crops when grown as monocultures on compatibility with trees, tolerance to various stresses, rooting depth, ability to improve soil health, invasiveness, and value for pollinators and beneficial insects. An * marks the top cover crop species for the Midwest.

Species	Forb type	Growing season	Compatibility	Shade tolerance*	Flood tolerance*	Drought tolerance	Low fertility soils	Mowing tolerance	Juglone tolerance	Known allelopath	Rooting depth (ft)	Nitrogen source	Nutrient scavenge	Soil builder*	Subsoiler*	Topsoil loosener	Erosion preventer	Weed suppresser	Can be invasive	Bee forge value	Beneficial insects	Bloom period	Hardy thru zone
Ann. lespedeza	AL	WS	C	D	D	B	A	D	S	N	1	C	C	C	D	C	C	B	Y	D	D	Jul-Oct	8
Arrowleaf clover	AL	CS	B	D	D	C	D	B		N	1	B	B	A	C	A	B	B	N	B		Apr-Jul	6
Balansa clover	AL	CS		B	B		A					A	B	A	C	A	B	B	Y	A	C	Apr-May	6
Berseem clover	AL	WS		C	C	C	C	A		N	2	A	C	A	D	B	B	B	N	B		Apr-May	8
Black hay bean	AL	WS	A	D	C	B	C		T	N	1	C	C	D	D	D	D	C	N	C	C	Aug-Sep	9
*Black medic	AL	WS	B	C	D	D	C	B		N	1	C	D	C	C		C	B	Y	B	B	May-Sep	6
Burclover	AL	WA		C	C	C	B	A		N	1	B	D	C	F	C	C	B	Y	C	C	Mar-Jun	5
Chickling vetch	AL	WA		B		A	B	C			1	A	B	C	D	C	C	B	N	D	B	May-Jun	8
*Crimson clover	AL	WA	B	C	D	D	B	C	M	N	2	B	C	A	C	B	B	B	N	B	A	Apr-Jul	7
Cowpea	AL	WS		C	D	C	A			N	1	B	C	C	D	C	B	A	N	A	B	Jul-Sep	9
Field pea	AL	CS		D	D	D	D		M		1	A	D	C	D	B	C	C	N	C	C	May-Jun	7
*Hairy vetch	AL	WA	B	B	D	C	D	B	T	Y	1	B	D	B	C	B	C	C	Y	A	A	May-Jul	4
Lentil	AL	CS			D	A	C				1	B	C	D		D	C	D	N	C	B	Jun-Aug	5
Partridge pea	AL	WS		B	D	B	C	A		N		C		B			B	B	N	A	A	Jul-Sep	3
Soybean	AL	WS	A	D	C	B	B		T	N	1	B	C	D	D	D	D	C	N	C	C	Jul-Aug	9
Subclover	AL	WS	A	A	B	B	B	B		N		B	D	B			B	A	Y	B	B	Mar-Apr	7
Sunn hemp	AL	WS		D	D	B	B	F	T	N	4	A	C	A	A		A	A	N	B	C	Aug-Oct	9
Woolly pod vetch	AL	WA	B	B	D	B	B	B		N	1	A	C	A	C	B	C	A	Y	A	A	May-Jul	6
*Sweetclover	BL	CS	B	C	B	A	A	C	M	Y	3	C	D	A	A	A	B	B	Y	B	A	May-Sep	4
Alfalfa	PL	CS	D	D	C	A	D	D	S	Y	8	A	C	A	A	C	B	B	N	A	C	May-Sep	5
Alsike clover	PL	CS		D	A	C	C	C	M	N	1	A	D	C	D	C	B	B	S	B	A	May-Oct	
Bird-foot trefoil	PL	CS	C	D	A	B	B	B		N	3	B	B	C	B	B	B	A	Y	B	B	Jun-Sep	5
Crownvetch	PL	CS	A	A	D	A	B	B	M	Y	4	A	B	B	A	B	A	A	Y	A	C	May-Aug	4
Flat pea	PL	CS		C	D	C	B	F		N	4	B		B			A	A	Y	B	B	Jun-Aug	3
IL bundleflower	PL	WS	C	C	B	C	C	D		N	5	D	C	C		B	C	C	Y	B	C	Jul-Aug	5
Kura clover	PL	CS	B	B	C	C	B	C		N	2	B	B	B	C		B	B	N	A	C	Apr-Oct	4
Ladino clover	PL	CS	C	B	B	C	A	B	T	N	2	A	D	C	D	B	B	B	Y	B	C	May-Oct	5
*Red clover	PL	CS	B	D	B	B	D	B	T	N	3	B	C	B	C	B	B	B		B	C	Apr-Oct	4
Sainfoin	PL	CS		D	D	B	D	D		N	4	B			B			B	N	A	B	May-Jul	2
Tick trefoil	PL	WS	C	A	D	B	B		T	N		D		B	B		B	B	Y	A	A	Jul-Aug	2
White clover	PL	CS	C	C	B	D	B	A	T	N	2	B	D	B	D	B	B	B	Y	B	C	Apr-Sep	4
*Buckwheat	AB	WS	C	C	D	D	B	C	T	Y	1	F	C	C	F	B	D	A	Y	A	A	May-Sep	8
Forage radish	AB	CS		C	D	C	D			N	4	F	A	B	A	B	C	B	Y	B	B	May-Aug	6
Kale	AB	CS	A		D		D	D	S	N	2	F	B	C			B	A	N	A	A	May-Sep	
Mustard	AB	WA		C	D	C	C		S	Y	2	F	C	B	D	B	B	B	Y	A	B	Apr-Jun	5
Phacelia	AB	CS		D	B	C	C	D		N	3	F	B	C	D	C	D	C	N	A	A	Apr-Jul	8
Rapeseed	AB	WA		C	D	C	C			N	3	F	B	C	C	B	B	B	Y	A	B	Apr-Sep	7
Safflower	AB	WS			D	A	C	D			8	F	A	C	A			C	N	A	B	Jul-Aug	5
Sunflower	AB	WS		C	D	B	B		T	Y	4	F	B	C	A	C		C	N	A	A	Aug-Sep	9
Forage turnip	BB	CS			D	D	D			N	3	F	B	D	B	B	D	C	Y	B	A		6
Goldenrod	PB	WS	F	B	D	A	B	C	T	Y	7	F			B			A	Y	A	A	Aug-Oct	2
Milkweed	PB	WS		C	C	B		A	T	N	4	F					C	C	N	A	A	Jun-Aug	2
Perennial aster	PB	WS	D	C	C	B	B		T	Y	7	F					C	A	Y	A	A	Aug-Oct	3
*Ann. ryegrass	AG	WA	D	C	B	D	C	A		N	2	F	A	A	A	A	A	B	Y	F	D	May-Jul	6
*Cereal rye	AG	WA	B	C	C	B	A	C	T	Y	2	F	A	A	B	A	A	A	N	D	D	Apr-Jun	3
Forage corn	AG	WS	A	B	C	A	D	D	T	N	5	F	B	B	C	B	C	C	Y	D	D	Jun-Aug	
Foxtail millet	AG	WS	B	D	C	B	B	D	T	N	1	F	A	B	D	C	C	B	N	F	D	Jul-Oct	
Grain sorghum	AG	WS	D	D	D	A	C	D		Y	2	F	B	B	C	B	C	B	N	F	B	Aug-Sep	9
Japanese millet	AG	WS		D	A	B	A	D		N	2	F	A	B	D	D	A	B	Y	F	D	Jun-Jul	8
Pearl millet	AG	WS		F	C	A	B	D		N	1	F	A	B	C	D	A	B	N	F	D	Aug-Sep	9
*Spring oat	AG	CS	A	D	D	D	C	D	T	N	2	F	A	C	F	B	A	A	N	F	D	May-Jun	8
*Sorgh x sudan	AG	WS	F	D	D	A	C	D		Y	4	F	A	A	C	C	A	B	N	F	C	Jun-Oct	8
Sudan grass	AG	WS	F	D	D	A	D	D		Y	4	F	A	A	C	C	A	B	N	F		Jul-Aug	9
Teff lovegrass	AG	WS		D	B	A	C		T	N	1	F	C	B	D	C	A	C	Y	F		May-Jun	3
Triticale	AG	CS	B	C	C	C	B	C	T	Y	2	F	B	B	C	C	A	B	N	F	D	May-Jun	4
*Winter barley	AG	WA	C	D	C	B	B	A	T	Y	2	F	A	B	C	B	A	B	N	F	D	Apr-Jun	7
Winter wheat	AG	WA	B	C	D	B	B	A	T	Y	2	F	B	B	C	C	A	B	Y	F	D	May-Jun	4
Bermuda grass	PG	WS	B	D	B	C	C	C		Y	1	F	B	B		B	A	D	Y	F			4
Brome grass	PG	CS	D	B	C	B	C	B	T	Y	4	F	B	B	B	B	A	A	Y	F	F	May-Jun	2
E. gamagrass	PG	WS		B	C	B	C	C		N	7	F	B	A	A	B	A	B	N	F	F	Jul-Aug	5
KY blue grass	PG	CS	B	B	D	C	D	B	T	N	1	F	B	B	D	A	B	C	N	F	F	May-Jul	2
Little bluestem	PG	WS		C	D	A	B	D		N	6	F	B	B	B	B	B	C	Y	F	C	Aug-Sep	3
Orchard grass	PG	CS	C	B	D	C	B	D	T	N	4	F	B	B	B	C	A	C	N	F		May-Jun	5
Per. ryegrass	PG	CS	C	C	C		C			N	3	F	B	A	A	C	B	C	Y	F	D	Jun-Aug	
Red fescue	PG	CS	B	B	B	B	C	A	T	Y	3	F	B	B		A	B	B	Y	F	D	May-Jun	2
Redtop	PG	CS	B	C	A	C	A	B	T	N	4	F	B	B		B	A	B	Y	F		May-Jun	2
Switchgrass	PG	WS		D	B	B	A	D		N	9	F	B	A	A	A	A	A	Y	F		Aug-Sep	4
Tall fescue	PG	CS	F	C	B	B	C	A	T	Y	2	F	B	A	B	B	A	A	Y	F		Apr-Jun	3
Timothy	PG	CS	C	C	C	D	B	C	T	Y	2	F	D	A	D	C	A	C	N	F	F	May-Aug	2

Editor's note: It is surprisingly difficult to print tables . For a digital version of these tables, please see ourwebsite or contact me at nngaeditor@gmail.com

Table 2. — Agronomic information of candidate cover crops as to growing season, form, height, acceptable soil pH ranges, planting information, time to emergence, growth rates, moisture use, productivity, and feed value for primarily cattle. An * marks the highly recommended Midwestern species.

Species	Plant architecture	Mature height (inches)	Acceptable soil pH range	Times to seed in the Midwest	Fall seed (weeks)	Soil temperature (ºF)	Seeding rate (lb/acre)	Sowing depth (in)	Days to emerge	Establishment rate	Growth rate	Moisture use	Productivity (dry tons per acre)	% Crude protein	Forage value	Grazing value*	Toxicity issues
Ann. Lespedeza	SE	15-20	5.0-7.0	W, Sp	----		15-30	0.3-0.5		B	B	A	1-2	13	C	B	
Arrowleaf clover	SE	30-40	6.0-7.5	LSu, EF	4-8		9-11	0.2-0.5		C	B	C	2-3		B	B	
Balansa clover	SE	12-36	4.5-8.0	ESp, LSu	5-8		5-10	0.1-0.2		A	A	C	2-4	20	A	A	B
Berseem clover	E	12-20	5.5-7.8	ESp, LSu	5-6	42	15-20	0.2-0.5	7	C	A	A	3-5	25	B	A	
Black hay bean	E	30-36	5.5-7.2	ESu	----	65	40-60	0.5-1.0		B	A	C	2-4	30	B	B	
*Black medic	SE	12-24	6.0-8.0	LW, ESp	----	45	10-15	0.1-0.3			B	B	1-2	20	C	B	
Bur clover	P	6-24	5.5-8.2	LSu-EF	2-6		20-25	0.2-0.5			B	C	1-3	18	C	B	B
Chickling vetch	V	24-48	5.5-7.5	ESp	6-8	45	30-40	0.5-1.5			C	A		30	D	F	T
*Crimson clover	SE	8-20	5.0-7.5	W, ESp, LSu	6-9	42	15-25	0.1-0.3	7	A	C	B	2-3	21	A	A	B
Cowpea	SE	18-24	4.5-7.5	LSp, ESu	----	58	20-30	1.0-1.5			A	A	2-4	20	B	C	
Field pea	V	18-48	5.0-7.0	ESp, LSu	4-8	41	40-90	1.0-2.0	9	C	B	B	2-3	14	A	B	
*Hairy vetch	V	24-72	5.5-7.5	LSu, EF	4-7	60	25-45	1.0-1.5	14	D	B	B	1-3	16	D	D	T
Lentil	SE	12-30	4.4-8.2	ESp, EF	1-4	40	10-15	1.0-1.5				A		14	C	C	
Partridge pea	SE	24-36	5.5-7.5	ESp-LSp	----	70	10-30	0.2-0.7		B	B	C			C	C	T
Soybean	E	24-36	5.5-7.8	LSp, ESu	----	60	40-60	1.0-2.0		B	A	C	2-4	17	C	C	N
Subclover	P	6-12	5.0-8.0	ESu, LSu	2-6	38	20-30	0.5-1.5		C	B	A	2-4	28	B	B	B
Sunn hemp	E	36-99	5.5-8.4	ESu	7-9	68	15-20	0.5-1.5	4	B	A	B	2-5	30	D	D	T
Woolly pod vetch	V	18-24	6.0-7.5	LSu, EF	1-2	60	30-60	0.5-1.5	14	C	A	B	2-4	17	B	B	
*Sweet clover	E	18-90	6.0-7.5	W, Sp, Su	>6	42	10-15	0.2-0.5	7	C	B	C	2-3	15	D	D	B
Alfalfa	E	18-42	6.0-8.5	ESp, LSu, EF	4-8	34	10-20	0.2-0.5	7	D	B	F	4-6	18	A	A	B
Alsike clover	SE	24-48	5.5-7.5	W, Sp, Su	6-8		4-8	0.2-0.4	8	B	C	F	1-2	20	B	B	T
Bird's-foot trefoil	SE	18-27	5.0-7.0	Sp, F	8-9	65	5-10	0.1-0.5	10	D	B	B	2-4	18	C	B	P
Crownvetch	SE	12-48	5.5-7.7	Sp, ESu	----	68	5-15	0.2-0.5		D	B		2-4	18	D	C	
IL bundle flower	E	24-54	5.5-8.0	ESp, F	1-2	68		0.5-1.0		C	C	C			C	A	T
Kura clover	SP	6-12	5.5-7.0	ESp, LSu	2-6	41	8-12	0.2-0.5	12	D	C	C	1-4	24	C	A	B
Ladino clover	SE	40-50	5.5-7.0	ESp, LSu	5-6	40	1-4	0.3-0.5		D	C	C		25	B	A	B
Flat pea	V	48-72	5.5-7.0	ESp, LF	0-2		15-20	1.0-1.5		D	B	C	1-2		D	B	T
Red clover	E	12-36	5.5-7.5	ESp, LSu	2-6	41	5-12	0.2-0.5	9	B	B	C	1-3	15	A	A	B
Sainfoin	E	18-36	6.0-8.5	Sp, EF	2-6		20-35	0.5-1.0	5	C	B	D	3-5	17	A	A	
Tick trefoil	E	36-72	5.5-7.0	Sp, LF	----	68	3-10	0.1-0.3		B	B	A			C	C	B
White clover	P	3-18	5.5-7.0	Sp, EF	>8	40	1-4	0.2-0.5	9	D	C	C	1-3	25	C	A	P
*Buckwheat	SE	24-60	5.0-7.0	LSp, ESu	>8	50	20-40	0.5-1.5	5	A	A	B	1-2	5	F	F	
Forage radish	E	12-18	6.0-7.5	ESp, LSu	3-9	45	4-15	0.2-0.7	3	A	B	F	2-4	28	B	C	
Kale	E	12-30	5.5-7.2	Sp. LSu	3-4	45	4-8	0.2-0.8	12	A	A	C	2-4	20	C	C	P
Mustard	E	24-60	6.0-7.5	Sp, LSu	4-8	40	5-10	0.2-0.7	6	A	B	D	2-4	12	D	C	P
Phacelia	SE	6-48	6.2-8.0	ESp, F	5-7	37	3-7	0.1-0.5	8	C	A	B	1-2		D	D	
Rapeseed	E	36-60	5.5-7.5	Sp, LSu, F	4-6	41	3-5	0.2-0.6	7	B	A	C	1-3	14	D	B	P
Safflower	E	12-48	5.5-6.5	ESp, LSu	----	40	25-35	0.5-1.0	12	C	A	F		12	B	C	
Sunflower	E	36-72	5.5-7.5	Sp - ESu	----	70	5-10	0.1-1.0	4	B	C	D		12	D	B	
Forage turnip	E	6-18	5.4-6.7	Sp – Lsu	3-9	45	2-4	0.2-0.5	7	B	A	F	2-3	16	F	A	P
Goldenrod	E	18-48	5.0-7.5	ESp, LF	----		0.5-1	0.1-0.3		C	A	C			D	C	
Milkweed	E	24-72	5.5-7.5	LF, EW	----			0.2-0.5		C	C				D	F	T
Perennial aster	E	18-56	5.0-7.5	LF, EW	----			0.1-0.3		B	B				D	D	
*Ann. ryegrass	E	15-36	5.0-7.8	ESp, LSu	3-9	40	15-25	0.2-0.8	10	A	B	C	2-4	13	C	B	
*Cereal rye	E	36-72	5.0-8.0	LSu – F	0-5	34	60-99	0.5-2.0	6	A	A	F	3-5	9	C	B	N
Forage corn	E	48-72	5.5-7.5	LSp, ESu	----		8-15	1.0-1.5		B	A	F	5-7	10	C	B	N
Foxtail millet	E	24-60	5.0-7.0	ESu, EF	----		20-30	0.8-1.2		B	A	A	1-2	15	B	B	N
Grain sorghum	E	18-36	5.5-7.5	LSp, ESu	----	65	10-20	1.0-2.0	10	A	A	C	3-4	18	B	B	P
Japanese millet	E	24-48	4.7-7.4	ESu	----	65	12-20	0.5-0.8	4	B	A	B	1-2		B	A	N
Pearl millet	E	36-72	4.8-7.5	ESu, LSu	----	60	20-25	0.8-1.5	7	B	A	A	2-6	13	B	A	N
*Spring oat	E	24-60	4.5-7.5	Sp, EF	6-8	38	40-90	1.0-2.0	6	A	A	C	1-4	12	B	A	K
*Sorgh x sudan	E	54-96	5.5-7.0	LSp, ESu	6-9	65	10-20	0.5-1.5	10	A	A	C	4-5	18	A	B	P
Sudan grass	E	54-96	6.0-7.0	LSp, ESu	6-9	65	15-50	0.5-1.0	10	A	A	B		11	B	A	P
Teff lovegrass	E	20-50	5.5-7.0	LSp, ESu	4-9	65	5-7	0.1-0.2	4	D	A	C	2-6	14	A	C	N
Triticale	E	18-50	5.2-7.1	ESu, Su, F	4-9	38	40-70	0.7-1.5	7	B	B	F	2-4	13	C	B	
*Winter barley	E	18-36	6.0-8.5	Sp, LSu, EF	3-9	38	60-90	0.7-2.0	7	B	B	A	1-5	12	B	B	N
Winter wheat	E	24-48	6.0-8.0	Sp, LSu, EF	0-4	38	50-99	0.7-1.5	7	B	B	D	2-4	10	C	B	N
Bermuda grass	P	4-12	5.0-8.5	Sp	----	65	7-10	0.1-0.3	10	D	B		4-6	7	C	B	B
Bromegrass	E	24-48	5.5-7.5	ESp, EF	5-7		10-20	0.2-0.6	6	C	A	C	2-4	15	A	B	
E. gamagrass	E	12-48	5.1-7.0	W, ESp	----	65	8-20	1.0-1.5		D	A	F	3-5	17	B	A	
KY bluegrass	E	15-30	5.9-8.0	ESp, EF	2-6	59	10-20	0.2-0.5	18	D	C	F			B	A	N
Little bluestem	E	24-48	5.5-7.5	W, Sp, LF	0-2	50	10-15	0.1-0.2	10	D	B	B		8	D	C	
Orchard grass	E	24-48	5.5-8.0	ESp, EF	4-8		5-20	0.1-0.5	13	B	B	A	2-4	12	B	B	
Per. ryegrass	E	12-30	5.0-8.0	ESp, LSu	4-8	40	15-30	0.2-0.5	5	B	B	D	2-5	16	A	B	T
Red fescue	SE	16-40	5.0-7.5	ESp, LSu	0-2		15-40	0.1-0.3	12	C	C	D			D	C	T
Redtop	SE	20-36	4.5-8.0	ESp, LSu, EF	6-7		3-6	0.1-0.3	13	C	A	C		9	C	C	T
Switchgrass	E	36-72	4.5-7.5	LSp	----		2-10	0.2-0.5		C	A	C	5-9		C	B	
Tall fescue	E	24-54	4.7-9.0	ESp, F	0-4		10-25	0.3-1.0	9	B	A	B	2-4	19	C	C	T
Timothy	E	24-42	5.2-7.5	Sp, LSu, EF	2-6		5-10	0.2-0.5	13	B	C	B	2-4	11	C	B	