Review paper

Utilization of Cover Crops for Sustainable Agriculture

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Abstract
Modern agricultural production is showing growing interest in the use of cover crops, mainly short-season annual crops grown either as winter pre-crops for main summer crops or summer post-harvest crops. Cover crops are usually grasses and legumes, regarding its purpose. Planting cover crop needs to be fast, in order to provide as much time as possible for the vegetation, together with preservation of soil resources. Advantages of cover crop can be achieved by savings through reduced fertilizers and pesticide applications can influence substantially lower costs for subsequent cash crop, whereas long-term savings through better soil quality, reduced soil erosion, increased organic matter content, improved soil physical properties, reduced nitrate leaching and enhanced nutrient cycling are still poorly observed as the real benefit for growers.

Keywords: cover crops, grasses, legumes, establishment, termination

Introduction

Modern agricultural production is showing growing interest in the use of cover crops, mainly short-season annual crops grown either as winter pre-crops for main summer crops or summer post-harvest crops. Beside two usual reasons for establishing cover crops, such as additional yield and bio-mass between two main crops (Stipešević et al., 2011), cover crops can presents many additional functions, thus improving sustainability and biodiversity of traditional crop rotations (Bavec et al,. 2012). The most important fact is that agricultural land does not have to be taken out of production of main cash crops in order to incorporate cover crops into cropping systems, and new trend of growing bio-energy crops is less jeopardizing food production security if cover crop is utilized as the source of bio-mass for bio-energy (Kemp, 2011). The best use of cover crops maximizes the benefits of cover crop usage, without reducing the yield or quality of commercial cash crops. Potential drawbacks, such as cooler soils in the spring, or additional cost of seeding the cover crop, must be also considered for each cover crop – cash crop combination.

Cover crops roles in sustainable crop rotations

Soil surface coverage and soil physics improvement

It has been estimated that the USA has lost 30% of its agricultural soil in the past 200 years due to agricultural practices that do not return organic matter to the soil and that leave bare fallow soils for a significant part of the vegetation season (USDA, 1965). Erosion has long-term impact at society costs due to loss of agricultural productivity, pollution of water and aquatic habitats as well as sedimentation of rivers, fresh water catchments and reservoirs,

river estuaries and sea water in coastal parts. There are also short-term costs of erosion for farmers, where USDA estimates around 80 USD worth of fertilizer per hectare yearly through the soil runoff from arable fields. Cover crops can help reduce soil erosion by keeping the soil covered during high rainfall periods when it would normally be bare. Different sources also report improved soil structure, stability and permeability, decreased crusting, and increased water infiltration (Wilson et al., 1982; Stipešević and Kladivko, 2005).

Addition of organic matter to the soil

Organic matter provides benefits to the soil and the subsequent crop in many different ways (Prunty, 2009). Organic matter improves the physical condition of the soil by improving soil tilth, stability of soil aggregates, water infiltration, air diffusion, and by reducing soil crusting. The addition of organic matter can also increase the populations of soil microbes and earthworms, which in turn, contribute to efficient nutrient cycling and improvements in soil structure (Bautista-Zuniga et al., 2008). Finally, organic matter additions can also increase nutrient retention in the root zone.

Nitrogen soil enhancement

Grass or non-leguminous cover crops can help keep N in the plant-soil system by utilizing residual N that would otherwise be leached into ground water. Leguminous cover crops, such as cowpea, soybean, and velvetbean, can "fix" higher nitrogen amounts for use by subsequent crops by symbiotic *Rhizobium* bacteria, which convert atmospheric nitrogen into a form that the legume can use for its own growth. In both cases, when cover crop decomposes by soil bacteria, the nitrogen is released to subsequent cash crops.

Nitrogen in the aboveground biomass of the cover crops varies considerably within species, where nitrogen available from cover crops can be in the range from 30-200 kg N per hectare. This nitrogen is mineralized over an extended period of time, with an average of 50% of the total N contained in the cover crop available to subsequent crops.

Achieving synchrony of N release from decomposing cover crop residues and cash crop nitrogen demand is expected to enhance the overall efficiency of use. Timing of cover crop termination can substantially affects N availability. Generally, the more mature the cover crop, the higher the C:N ratio and the slower the decomposition. Better utilization of N is important to prevent N pollution of surface and groundwater through runoff and leaching.

Leaving cover crop residues on the soil surface, rather than incorporating them, has advantages and disadvantages with regard to efficiency of utilization of cover crop N. Maintenance of surface residues can result in increased losses of cover crop N to the atmosphere through denitrification, but, on the other hand, immobilization and slower residue decomposition can result in reduced leaching losses. Also, a higher concentration of crop residues and organic matter near the soil surface can increase the diversity of microorganisms and fauna at the surface, which can result in greater recycling of N in the soil ecosystem.

Weed suppression

While the cover crop is growing, its pure development will suppress the germination and growth of some weeds through competition and shading. When killed and left on the surface as a mulch, cover crops continue to also suppresses weeds, primarily by blocking out Sun radiation, both light and heat. Cover crops can also suppress weeds through chemical release, either by decomposition or by active release of chemicals (allelopathy), and praxis of using cereal cover crops such as rye, wheat, barley, oats, sorghum, and sudangrass to suppress weeds is very frequent. Weed suppression is also detected by legumes, such as crimson clover, hairy vetch and others, which residues and leachates also can depress weed

germination (Teasdale et al., 1991; Johnson et al., 1993). Weed suppression by cover crops gains on its importance, especially in the light of building weed resistance against herbicides, even ones based on glyphosates (Simić et al., 2013).

Impact on plant diseases

Pathogens can either be enhanced or inhibited by cover cropping systems, because soil microorganisms that cause disease can by affected by decreases in temperature, increases in moisture, reductions in soil compaction and bulk density, and changes in nutrient dynamics (Hartz et al., 2005). The taxonomical relation of cover and cash crops is also important, due to common diseases, which cycles can be either interrupted or prolonged. Some cover crops have also been shown to reduce nematode populations, including velvetbean, sorghum-sudangrass, and sunhemp (Hagan et al., 1998; Stone, 2012).

Impact on insect populations

Cover crops may both attract or repeal beneficial and pest insects into cropping system. Both can disperse to cash crops when the cover crop matures or dies (Altieri and Schmidt, 1986; Tillman et al, 2004). Prior to the arrival of important insect pests, beneficial insects attracted into an area by a cover crop may reach sufficient population densities to maintain pest populations in adjacent crops below economic threshold levels. Also, attraction of honeybees and bee pasture can be crucial for better sustainability of a whole farm.

Decision which cover crop(s) to use

The desired purpose of the cover crop will determine the most appropriate crops for cover crop. If the purpose of a cover is to provide readily available, biologically-fixed N for subsequent crops, which is obligatory for some farming systems, such is organic production, then cover crop choice should be a legume like cowpea, soybean and wetch, which fixes nitrogen and has a low C:N ratio. If the cover crop will be managed as a surface mulch for weed suppression, then the choice of cover crop is in crops with high C:N, heavy biomass production and previously demonstrated weed suppression characteristics, such as sorghum-sudangrass, rye and other grasses.

Mixtures of cover crop species should be also observed, in order to optimize the benefits associated with cover crop use. Mixtures which include species that establish quickly can reduce soil erosion. Above-ground biomass, and consequently N in the above-ground biomass, can be increased by a mixture that can utilize more below-ground and above-ground niches for nutrients, water, light and heat. For example, a deep rooted cover crop can be combined with a shallow rooted cover crop to utilize water and resources in different soil profile depth, or even to penetrate through the plough pan, in order to increase available water resources for subsequent cash crop.

Competition for soil N in mixed stands results in increased biological nitrogen fixation by the legume. Cereal crops usually germinate and establish effective root systems more rapidly than legumes and effectively lower soil N concentration. Since nodulation of legume roots and fixation of atmospheric N_2 by legumes is generally greater when soil N concentration is low, nodulation and nitrogen fixation is increased in mixtures.

Nitrogen cycling can also be manipulated with mixed cover crop species. Combining plants with high C:N ratios (mature cereals) with plants that have low C:N ratios (legumes) can influence mineralization of cover crop residues. The release of nitrogen from residues can be more properly timed with subsequent crop uptake. Therefore, both nitrogen immobilization and large flushes of nitrate can be moderated. This can help to optimize the efficiency with which fixed nitrogen is used by subsequent crops.

Planting mixtures of cover crops can take advantage of the allelopathic potential of the cover crops to suppress weeds. Allelopathic suppression of weeds has been shown to be a species specific phenomenon, therefore a broader spectrum of weed control may be possible by growing a mixture of cover crop species, each contributing allelopathic activity towards specific weed species.

Mixtures can also be planted to influence insect populations. Cover crop species, regardless of biomass or biomass-N production potential, could be included a mixture if they were known to attract important beneficial insects into the cropping system. This is also exploited in so called biodiversity belts, which can be proliferated by cover crop mixtures. Also, some production systems, such as organic and integrated crop production, have requires and/or stimuli for environmental benefits achieved on this way. Importance of different mixture cover crops and their rooting also can be expressed in reduced soil tillage systems, where is possible buildup of certain less mobile nutrients at certain depths, due to lack of inverting soil, such is the case with mouldboard ploughing (Jug et al., 2013). Cover crop growth would be viable strategy in the uptake and distribution of these nutrients closer to rizosphere of the cash crop.

Establishment of cover crop

In many cases, planting cover crop needs to be fast, in order to provide as much time as possible for the vegetation, together with preservation of soil water reserves (Birkas et al., 2008). Therefore, soil tillage for cover crop needs to reflect these requirements, and reduced soil tillage, or even no-till seeding (Fuhrer, 2013), can be the best possible choice for cover crop soil preparation. Cover crop population density in some cases can be satisfactory even by broadcasting seed at the soil surface in previous crop stubble (Stipešević et al., 2008). Today's modern concepts of soil tillage tools can integrate also need for cover crop quick establishment in different type's multitiller, where seeding apparatus is an integral part of the tool. So, only one pass by this type of the tool suffices for soil preparation and cover crop seeding.

Cover crop termination methods

Cover crop purpose defines its termination. If it is purpose seed production, cover crop can be harvested by combine with needed adaptations for seed size. Cover crops that will be left on the surface as a mulch for no-till production need to be killed, either with chemicals or mechanical ways. In systems where the goal is to reduce chemical use, mechanically killing the cover crops is desirable. These methods for cover crops mechanical killing can be different, such as mowing, undercutting, or rolling with regular or special rollers, all of them showing different quality of cover crop termination and possibility of cover crop regrowth, regarding different environmental factors. In some cases, termination by cattle grazing is also viable option.

Conclusion

Cover crops are definitely part of sustainability of modern crop production, regardless whether grown for the yield, biomass or some other benefits. The highest issue growers can face is additional cost for seed and planting cover crops, especially where some cover crop seed is not readily available. But, savings through reduced fertilizers and pesticide applications can influence substantially lower costs for subsequent cash crop, whereas long-term savings through better soil quality, reduced soil erosion, increased organic matter content, improved soil physical properties, reduced nitrate leaching and enhanced nutrient cycling are still poorly observed as the real benefit for growers.

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