

Making Cover Crops Work for You

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Cover crops can provide numerous benefits to crop production. Producers have historically adopted cover crops to limit soil erosion and conserve residual soil mineral nitrogen (N) following cash crops (particularly maize) (Meisinger et al., 1991; Shipley et al., 1992).

More recently, increasing climate variability (drought and floods), emphasis on soil health, cost of mineral fertilizer, and threats from herbicide-resistant weeds have driven greater interest in cover crops. The degree to which a given cover crop provides a benefit is largely dependent on climate, soil, genetics, and management. Since cover crop biomass levels are directly correlated with benefits provided, management should be optimized to achieve maximum potential biomass given climate and soil constraints. Failure to manage cover crops effectively can actually be detrimental. For example, early termination of cover crops can release N at a time when no crop is present, leading to greater N losses because soil N is highly mobile and will leach or run off when not absorbed by plants (Campiglia et al., 2011). Early-killed cover crops reduced N leaching by 52% compared to a 75% reduction when cover crops were allowed to grow later into the spring (Heinrich et al., 2014).

Different cover crop species provide different benefits to different degrees, which is affected by management. Small grain cover crops such as cereal rye, grow rapidly and produce substantial biomass, making them excellent at scavenging residual inorganic N, preventing erosion, and building soil organic matter. However, cereal rye residues do not release substantial N during the subsequent growing season and can even cause N immobilization during decomposition (Poffenbarger et al., 2015c). Cereal rye is the most commonly planted cover crop in North America due to hardiness, low seed cost, and large biomass potential. Climate, soil, available reactive N, and management have all been identified as primary factorsinfluencing cereal rye provision of benefits, which is dependent on cereal rye biomass production. Cereal rye biomass productionlargely depends on climate(i.e., temperature during the growing season and precipitation) and N availability (Mirsky et al., 2017). Cereal cover cropmaturationfrom seedling through floweringdepends on temperature andphotoperiod (Mirschel et al., 2005; Travis et al., 1988). However, soil moisture and N limitationscan cause







cereal rye to mature faster, which causes less biomass production (Davidson and Campbell, 1983; Mirschel et al., 1995). Cultivarselection also influences cereal rye growth (Mirsky et al., 2009, 2011). Culturalmanagement practices such as planting date, termination date, seeding rate, establishmentmethod, and cultivar affect growth rates, shoot biomass, and N content of cereal rye. Mirsky et al. (2011) showed that biomass increased by about 2000 kg ha–1 with each 10-d delay in spring termination between 1 May and 1 June.

Winter legume cover crops such as hairy vetch fix atmospheric N2 and release N during decomposition, reducing the amount of N fertilizer required for succeeding crop. Hairy vetch can product more than 50 kg ha–1 total N when planting and termination dates are optimized (Mirsky et al. 2017). However, only 40 to 75% of N accumulated by a hairy vetch cover crop is typically available to a succeeding maize (Zea mays L.) crop in time for the maize to make use of it (Clark et al., 2007; Seo et al., 2006), often leaving a portion of corn N demands unsatisfied. Therefore, to achieve optimum corn yields in cover-crop based systems, the N supplied by hairy vetch usually needs to be supplemented by fertilizer or manure. Part of the reason not all of the N accumulated by hairy vetch is available to maize is due to the early release of N from hairy vetch biomass prior to peak maize N demand. This rapid N release from hairy vetch residues may lead to early-season inorganic N losses (Rosecrance et al., 2000). Finally, legume cover crops such as hairy vetch can cost up to 10 times as much to establish as grasses due to their greater seed cost and weaker emergence (Snapp et al., 2005).

A grass-legume cover crop mixture can merge the benefits of each component species, while attenuating their negative attributes. For example, hairy vetch-cereal rye cover crop mixtures have been shown to provide greater aboveground biomass production, inorganic N scavenging, and weed suppression than hairy vetch monocultures, and greater aboveground N content than cereal rye monocultures (Poffenbarger et al. 2015a; Mirsky et al. 2011; Figure 1). The intermediate C/N ratios of hairy vetch-cereal rye mixtures contribute to more moderate N release and decomposition rates relative to hairy vetch monocultures, which can result in improved synchrony of N release and crop demand (Poffenbarger et al., 2015b; Figure 2). Synergistic mixture effects arise because legumes and grasses can use resources in complementary ways. Legumes grown in mixture with a grass are forced to rely more on biological N fixation than soil N sources, because grasses compete with legumes for soil N (Poffenbarger et al. 2015b), and the ability of legumes to biologically fix N2 allows grasses in mixtures to accumulate higher concentrations of tissue N because legume roots exude N (Hayden et al., 2014). Finally, grasses and legumes differ in their aboveground architecture, allowing mixtures to capture light more efficiently than monocultures (Keating and Carberry, 1993).







Since interest has grown in producing more cover crop biomass for soil health, forage, water and N management, and weed suppression, producers are now delaying cover crop termination prior to maize planting to maximize the provision of these benefits. Delayed cover crop termination is not usually problematic when the cover crop in question is a legume. However, high levels of cereal cover crop biomass prior to cash crop planting can significantly influence soil inorganic N levels and N availability through the immobilization of N.This trend poses a challenge in maize production as producers have increasingly switched to split-N applications (i.e. part of the fertilizer applied at planting (starter) and the rest applied at sidedress) to improve N use efficiency for both optimal yield and environmental stewardship. Delayed cereal cover crop termination contributes cover crop biomass with higher C:N ratios to the system. Current maize N fertilizer recommendations do not account for the potential N immobilization caused by large amounts of cereal cover crop biomass. Nitrogen application recommendations for maize range from 90 to250 kg N ha-1 depending on region and anticipated yield (Beegle and Durst, 2003; Bundy, 1998). Fertilizer applied out of synchrony with corn uptake is often lost from the cropping system via leaching, runoff, and denitrification. Such losses represent an economic inefficiency impacting farmer profitability and have significant consequences for water quality, including the development of hypoxic zones in the Chesapeake Bay and Gulf of Mexico (Mitsch et al., 2001).

In a meta-analysis of 50 years of cover crop studies, cereal covers did not significantly influence crop yield in contrast to no cover crop (Marcelo and Miguez, 2017); however, this work did not distinguish the effects of N management and cereal rye biomass. In general, studies that applied 160 kg ha-1 of N at planting, did not observe differences in yield potential when cereal rye biomass levels were less than 7500 kg ha-1 (Duiker, 2005; Crandall et al. 2005). If no starter fertilizer was applied and all N was applied at sidedress, yield effects are observed at cereal rye biomass levels as low as 2500 kg ha-1. There does appear to be a benefit from delaying timing of planting after cereal covers are killed regardless of the cereal cover crop biomass levels (Clark et al., 1995).

Water management with conservation tillage and cover crops

Across US production regions, climate change is expected to cause increased flood and drought intensity, altered rainfall patterns, and greater frequency of extreme heat events (Allan and Soden, 2008; Gornall et al., 2010; Rosenzweig et al., 2014; Trenberth et al., 2014). The recent 20-yr trend has been towards wetter springs and drier summers, and an increase in the frequency of extreme rainfall events (Mourtzinis et al., 2016). These weather pattern changes represent a challenging situation, especially in regions with an eroded landscape with many soils being highly weathered and acidic with low organic matter (OM, below 1-3%) and







poor structure (Radcliffe et al., 1988; Simoes et al., 2009). Moreover, extreme rainfall events combined with unprotected soil leads to both soil erosion and surface crusting; the latter exacerbates surface runoff and limits infiltration and recharge of soil during rain events (Alvarez et al., 2017). These factors contribute to greater nutrient losses and negatively impacts estuaries. Conservation tillage systems have proven to be an effective management practice for maintaining and improving soil health (Blevins and Moldenhauer, 1995; Grandy and Robertson, 2007; Six et al., 2002; Zibilske and Bradford, 2007). Unfortunately, despite the proven benefits of conservation tillage, its full potential is not being realized. Conservation tillage can result in extensive soil surface crusting, impeding soil infiltration during rainfall events and leading to greater surface runoff (Merten et al., 2015; Shaver et al., 2002)

Cover crops are the essential component needed to maximize the benefits of conservation tillage and provide additional ecosystem services. In a global meta-analysis of water conservation strategies (crop rotation, cover crops, conservation tillage, perennials, and crop and livestock; ~90 published works), cover crops were second only to perennials, and this effect was magnified when cover crops were used in combination with conservation tillage (Basche et al., 2016). Across 40 on-farm cover crop strip trials initiated in 2016 throughout the mid-Atlantic and Southeast US (Figure 4), a significant effect was observed for cover crops on water infiltration as rainfall intensity increased (6 one-hour rain events from 1-4 inches of precipitation) (Mirsky, unpublished data). Greater cover crop biomass levels increased overall water infiltration as compared to bare strips and low cover crop biomass levels (Mirsky, unpublished data).

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Figure 1. Cover crop aboveground biomass in response to hairy vetch/cereal rye sown proportion for 4 site-years in Maryland. Curves represent model predictions (HV = hairy vetch, CR = cereal rye, Tot = total biomass). Error bars are ± 1 SE. interpretation







Figure 2. Proportion of mass remaining in mesh litter bags containing a range of hairy vetch (HV)/cereal rye (CR) biomass proportions and subjected to different pelletized poultry litter (PPL) management during the 2012 corn growing season. Each point represents the mean of three replicates of a particular cover crop biomass proportion and poultry litter treatment at a given time.







Figure 3. Volumetric SWC (0-30 cm depth) of CC and bare soil during high rainfall events (>15 mm day⁻¹) at 10 MD farms (2017).



