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FEATURE

Understanding equipment management for planting cover crops

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Cover crops are planted to protect and enrich soil in annual cropping systems. They are typically planted between periods of normal crop production or can be intercropped in widely spaced rows during the crop growing season. Cover crops benefit society by improving water quality (Abdalla et al. 2019), enhancing biodiversity (Beillouin et al. 2021), sequestering carbon (C) (Poeplau and Don 2015), and increasing resilience (Kaye and Quemada 2017). Farm level benefits of cover crops include reduced soil loss, weed suppression, soil nutrient management, and soil resiliency (Sarrantonio and Gallandt 2003).

USDA Census of Agriculture data indicate that acres planted to a cover crop rose from 10.3 million ac (4.1 ha) in 2012 to 15.4 million ac (6.2 ha) in 2017 (Wallander et al. 2021). Despite increasing in acreage, adoption of cover crops remains low. Eastern seaboard US states have the highest adoption rates and western states have the lowest. Three to eight percent of Midwest states' cropland had a cover crop in 2017 (Zulauf and Brown 2019). That same year, state and federal conservation programs distributed more than US$180 million to incentivize cover crop adoption on more than 5 million ac (2 ha) (Wallander et al. 2021).

Challenges or barriers to cover cropping identified in research include direct and opportunity costs (Lichtenberg 2004; Roesch-McNally et al. 2018), land tenure (Bergtold et al. 2012), cover crop fieldwork conflicting with corn (*Zea mays* L.) and soybean (*Glycine max* [L.] Merr.) production fieldwork (Roesch-McNally et al. 2018), seed availability (Martins et al. 2021), and the delayed realization of long-term private benefits (DeVincentis et al. 2020).

Machinery management impacts the cost of cover crop establishment. While seed cost is frequently recognized as the major expense in cover cropping (Martins et al. 2021), planting expenses are the second largest cost (Plastina et al. 2020). In addition to the direct costs of planting equipment, the opportunity costs associated with seasonal time conflicts and seed selection are inherent in farmer machinery management decisions.

Purchase price and operational costs, field capacity, and labor and power unit availability all affect successful cover cropping machinery decisions. Cover crop seed size and species life cycle have an impact on machinery choice. Similarly, machinery availability affects the species planted. This paper provides background into cover crop establishment, machinery choices for planting, machinery economics, and developments that might impact cover crop adoption.

COVER CROP ESTABLISHMENT

Cover crop establishment in a corn–soybean rotation can be challenging. Establishment is impacted by the interrelated factors of species selected, seed quality, weather, and planting method (Haramoto 2019). Individual species have recommended planting dates for reliable establishment (Midwest Cover Crop Council n.d.), which may conflict with cash crop production periods (figure 1).

Seed choice and the timing of seeding influences appropriate planting equipment. Seed-to-soil contact is more critical for cover crop species with larger seeds than for species with smaller seed sizes. Cover crop species with small seeds may be better suited to broadcast seeding. Cover crop seeding can be integrated with dry fertilizer application or fall tillage to reduce fall fieldwork activities.

Figure 1 shows the reliable establishment date range for various cover crop species in northwest Missouri. The gray area is the period between median planting and harvesting dates for corn in northwest Missouri. Only four cover crop species' reliable establishment dates extend past the median harvest date, limiting cover crop species that can be planted after harvest. Tractor and labor availability also limits the ability to plant cover crops postharvest.

Figure 2 presents modeled data to illustrate a situation a farmer may face. A farmer in northwest Missouri planting corn on May 14 could expect the corn to reach V6 to V8 growth stages between June 10 and July 2. After July 2, ground equipment of any style is not feasible in growing corn. Cereal rye (*Secale cereale*)'s reliable establishment date is from August 9 to November 11. Depending on weather, sufficient growing degree days for corn harvest could occur as early as September 25 or as late as October 29. Planting cereal rye with ground equipment is expected to be feasible unless soil conditions are unfavorable.

Seeding cover crops into standing cash crops, or interseeding, can take place at two time periods of the growing season. Early interseeding of cover crops in corn from V2 to V7 growth stages is occurring primarily in the northern Corn Belt (Brooker et al. 2020). Late interseeding occurs in corn from R4 to R5 growth stages, and soybeans from R6 to R8 growth stages (Mohammed et al. 2020). Interseeding provides the opportunity for a larger portfolio of cover crop species and can result in more biomass production. Herbicide programs may need to be adjusted to align with interseeding.

MACHINERY PLANTING OPTIONS

Equipment selection is affected by the desired cover crop species, the farm's existing equipment complement, amount of time available to plant the cover crop, and

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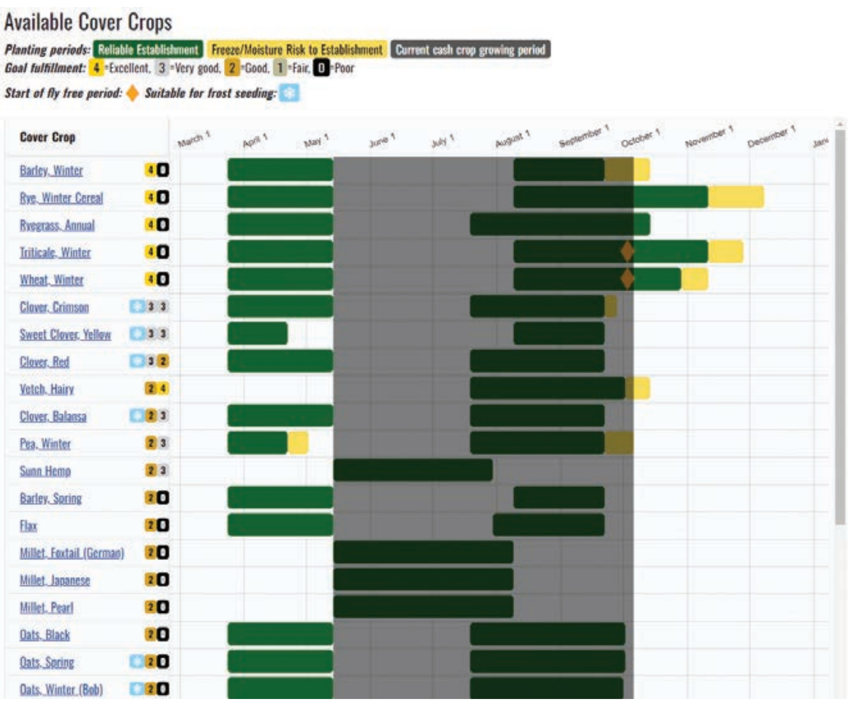
Figure 1

An example of cover crop establishment dates and corn growing period for northwest Missouri crop reporting district. Sources: Midwest Cover Crop Council (n.d.) Decision Tool establishment periods for Andrew County, Missouri. USDA National Agricultural Statistics Service (2023) Crop Progress Report for 50% corn planted to 50% corn harvested in northwest Missouri from 1998 to 2017.



the cost of purchasing and operating the equipment (Kientzy et al. 2023).

Postharvest cover crop planting is often conducted with existing farm machinery. This includes row crop planters, box or air drills, and pendulum, spinner, and boom spreaders. Recent planting methods include attachments that permit planting with combines and vertical tillage (VT) tools. Machinery availability differs across US crop producing regions.

Interseeding may require more specialized equipment than found on most row crop farms. High clearance machines and aerial equipment are used for later season cover crop seeding to minimize crop damage during seeding.

Row Crop Planters. A row crop planter can plant cover crops with minimal modifications. Benefits of using row crop planters include good seed-to-soil contact, excellent emergence, precise seed metering, and the ability to cover ground rapidly. Planters are expensive and seeding cover crops could cause undesired wear to the planter. Planters typically have wider row spacing than is ideal for cover crops and may work poorly when planting seed mixes or extremely small-seeded cover crops.

Using high-precision guidance (RTK) with split-row planters provides the ability to plant both winter-killed and cold-tolerant cover crops simultaneously. At spring planting, RTK guidance allows the operator to plant directly into the winter-killed row. The nutrients scavenged by winter killed crops can be more immediately available to the succeeding cash crop and provide a clean seedbed where the winter-killed row was located. Meanwhile, the cold tolerant species continue to produce biomass and reduce weed pressure prior to termination.

Drills. Drills offer compromise between seeding precision and flexibility. By measuring volume of seed rather than the number of seeds, drills accommodate a greater range of seed sizes, weights, and mixes than row crop planters.

Box drills are inexpensive but cover area slowly because of their limited width. Air drills are more expensive but offer faster seeding because of their increased width. Air drills may be equipped to apply fertilizer along with cover crop seed. The complexity and size of air drills requires a skilled operator and a larger tractor.

Achieving good seed-to-soil contact can be a challenge with end-wheel style box drills in no-till conditions. No-till box drills enable good seeding in tight soil or high residue situations by applying the weight of the frame, box, and seed payload to the row units by hydraulic force.

Pendulum Spreaders. Pendulum spreaders are an inexpensive cover crop seeding solution. A pendulum spreader's small capacity seed bin and a maximum 40 ft (12 m) spread width work well for the relatively light application rates of many cover crops. With lighter seeds, spreading width may suffer. Compared to other broadcast seeders, pendulum spreaders have a lower effective field capacity (measured in acres per hour) but can be effective in wet soil conditions.

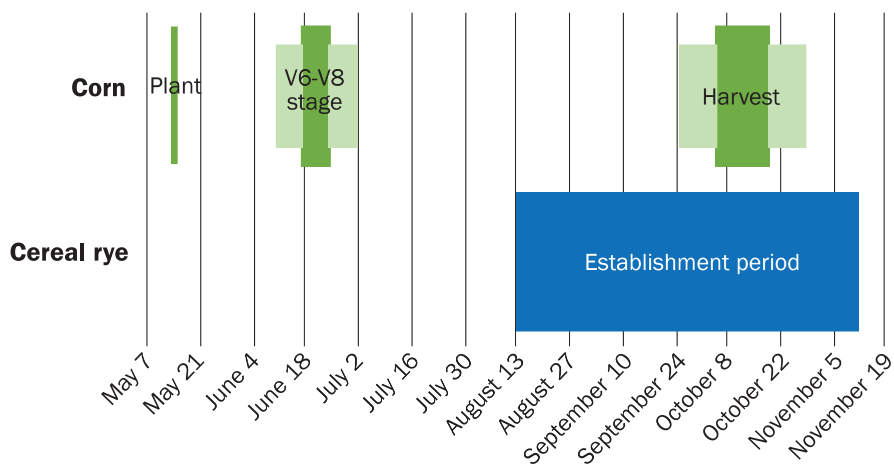
Spinner Spreaders. Spinner spreaders are affordable to purchase and operate. They can distribute product (i.e., seed or fertilizer) in large swaths at high speeds and simultaneously spread seed with fertilizer. Single disk spreaders can have poor spreading uniformity. Dual disk spreaders, with the two rotationally offset disks, result in better spread patterns.

Single disk spreaders typically have a small bin capacity and are mounted to the three-point hitch of a tractor. Dual disk spreaders are usually pull-type models capable of holding several tons of material.

Air Boom Spreader. Air boom spreaders use a blower and boom system to spread seed evenly across the length of the boom. Air booms reduce the effect of wind on the spread pattern, permitting the use of small-seeded cover crop varieties and mixes. Air boom spreaders have a rapid coverage rate and the ability to merge seeding with fertilizer application. They are more costly to own and maintain than other spreaders. They may also require a larger tractor because they are most often driven by the tractor's hydraulic system rather than the power takeoff (PTO).

Figure 2

Northwest Missouri modeled field progress and cover crop planting calendar. Sources: High Plains Regional Climate Center (2023) Corn GDD tool for 105 d maturity corn planted on May 14 in Andrew County, Missouri; 1980 to 2010 average GDD accumulation used to estimate time to V8 to V10 and blacklayer. Harvest is 30 d after blacklayer. Midwest Cover Crop Council (n.d.) Decision Tool establishment periods for Andrew County, Missouri.



Seed-to-soil contact is poor with all spreaders. Increased seeding rates may be needed to compensate for lower germination rates.

Vertical Tillage Attachments. Seeding attachments on VT implements integrate cover crop seeding with fall tillage practices, minimizing labor and equipment costs. Seeding attachments include a seed box and a blower-tubing system that delivers seed along the harrow portion of the VT tool to incorporate seed lightly into the soil, improve seed-to-soil contact, and boost emergence. Several manufacturers offer field ready cover crop seeding attachments for tillage tools. Some farmers have built units made with purchased components. VT tools are preferred by many farmers, because they leave more residue on the surface of the field and create less soil disturbance, but other tillage tools can also be used in cover crop seeding.

Combine-Mounted Seeder. Seeding attachments on combines integrate cover crop seeding and cash crop harvest. Seeding attachments for combines are like those used on VT implements but deliver seed to outlets behind the header or above the straw spreaders. Depending on the seeder configuration, the advantages and disadvantages of spinner spreaders and air boom spreaders apply to combine-mounted seeders.

Sprayer-Mounted Air Boom. High-clearance, self-propelled row crop sprayers have been retrofitted to permit cover crop seeding. These units use the sprayer's propulsion, frame, and boom, but replace the application hardware with a seed box, blower and metering system, and tubing to deliver seed. Retrofitting sprayers can be costly but they cover ground rapidly and offer a wide seeding window. The labor required to switch between spraying and seeding may be an obstacle.

High Clearance Spreader. Self-propelled high clearance spreaders have similar clearance as row crop sprayers. Tractor-drawn, pull-type models are limited by the tractor clearance. High clearance spreaders enable seeding into soybeans nearly anytime and into corn before the V8 to V10 growth stages. High clearance spreaders can merge cover crop seeding with in-season dry fertilizer application and are available in either spinner or air boom configurations.

Row-Based Interseeder. Interseeders precisely plant cover crops between rows of growing corn and soybeans using drill row units and an air delivery seed box. Crop height must be 2 ft (0.6 m) or less and not canopied to be effective. An interseeder offers excellent seed-to-soil contact. Field coverage rate is slow given reduced speeds to minimize crop damage. Width is typically restricted to 40 ft (12 m), but some custom-built units are wider. Interseeders are usually mounted to the tractor to better follow rows. Its weight must be minimized to maintain tractor stability. Farmers can combine this type of seeding with a mechanical weed control pass.

Aerial Application. Airplanes, drones, and helicopters can all seed cover crops. Advantages include no crop damage, no soil compaction, and fast application. Aerial application is most appropriate to small seeded and low seeding rate cover crops such as turnips (*Brassica rapa* L.), clovers (*Trifolium* spp.), and annual ryegrass (*Lolium perenne*). Species requiring a higher seeding rate are not well suited for aerial seeding.

Disadvantages of aerial seeding include greater expense than other methods (North Jersey RC&D 2021). For large, open fields, airplanes are fast and efficient. Drones and helicopters are better suited for smaller fields but may work more slowly at higher cost. Some farms purchase their own drones to allow more flexibility in application timing and strategy. Seed spread patterns and seed-to-soil contact is similar to high clearance spinner spreaders. Wind speed and direction, rotor wash, and seed density all affect the spread pattern of aerial vehicles. Prevention of offsite seed drift is important.

MACHINERY ECONOMICS

Machinery purchased for the sole purpose of cover cropping would have all ownership and operating costs allocated to cover cropping. Farmers typically use machinery they already own for other crop enterprises to seed cover crops. This creates ambiguity in the costs to plant a cover crop.

Machinery costs fall into use-related and overhead categories. Use-related costs accrue when the machine is being used. Fuel and lubrication, labor, and some repairs are use-related costs. They are a cash expense directly correlated with the hours of machine activity.

Overhead costs are incurred regardless of machine usage. Annual depreciation, interest, taxes, insurance, maintenance, and housing expenses are overhead costs that are much less correlated with the number of hours the machinery is used. Because these are sunk costs, many business managers do not consider them when estimating the cost of an additional activity such as cover crop planting.

Full budget accounting of machinery costs divides total overhead costs by the number of hours or acres the equipment is used to allocate costs to each activity for which it is used. It also allocates the use-related costs to the enterprise using the machine. In such a case, the cost of cover crop seeding is the sum of the use-related costs and overhead costs per acre. Custom operators use full budget accounting to determine their fees.

It is common for individuals to use a partial budget approach when estimating the cost of planting cover crops. Only the change in costs or incomes are considered in a partial budget. The additional costs include the use-related costs, especially fuel and labor. A partial budget may ignore some or all overhead costs, such as taxes and insurance, on the principle that they do not increase when used to plant cover crops.

Some farmers reduce use-related costs for seeding cover crops by joining the planting pass with another field activity that would occur regardless of cover cropping activity. For example, a farmer owning a high clearance air boom primarily to apply urea to 4 ft (1.2 m) tall corn can simultaneously plant cover crops by mixing seed and fertilizer. In this case, the farmer does not apply ownership costs of the spreader because its primary purpose is applying fertilizer. The farmer also minimizes use-related costs of this activity because adding seed to fertilizer has a negligible effect on the efficiency of applying fertilizer.

To the extent that existing equipment fosters cover crop planting, the partial budget approach permits emphasis of use-related costs. However, when equipment is purchased with full consideration of its ability to seed cover crops, the overhead costs are included in the partial budget. For example, purchasing a VT tool attachment that combines seeding with fall tillage might require all the ownership costs of the attachment to be allocated to cover crop seeding but may reasonably ignore the ownership costs of the VT tool and tractor that were going to till the field regardless of whether cover crops were planted.

Allocation of all costs will become appropriate as farmers consider cover crop seeding capabilities when purchasing equipment. Machinery costs may be less expensive when farmers are experimenting with cover crops but increase as the cover crop enterprise becomes an integral part of their machinery purchase decisions. Conversely, machinery costs per acre may decrease as equipment is allocated to both cash crop and cover crop acres.

POTENTIAL DEVELOPMENTS

New developments in agriculture create innovations. As cover crop adoption increases, opportunities to fill demand for cover crop equipment will become more prevalent and attract the attention of equipment manufacturers. If local, state, and federal financial incentives for cover crops increase acreage planted to cover crops, farmers and manufacturers will likely respond with innovations. Farmers may adjust their existing equipment complement to accommodate cover crop management. Manufacturing companies will modify and market cover crop seeding equipment to interested farmers. Companies that previously focused on dry fertilizer spreading may modify their product line to better facilitate cover crop seeding.

Equipment Optimization. Historically, farmers have purchased equipment without regard to seeding cover crops. As financial or ecological benefits from cover crops are realized, equipment purchases may be modified to meet both cash cropping and cover cropping needs. This may entail a greater analysis of equipment capacity. Precision farming companies focusing on field optimization might alleviate some of the time constraints of cover crop seeding (Cropzilla n.d.).

Effective field capacity (EFC) is the number of acres equipment can cover in an hour. Given the time constraints present during cover crop seeding, EFC becomes increasingly important. EFC can be increased with wider working widths, faster ground speeds, and larger seed bins.

Equipment Rental. Many county USDA offices and soil and water conservation districts have begun renting no-till drills to farmers planting cover crops (Southern Cover Crops Council n.d.). Rentals increase the supply of dedicated equipment and allow farmers to experiment before making further capital investments in machinery.

Custom Activities. Custom operators conduct field activities for farmers who either do not have the equipment or the time to conduct the activity. Custom operators can be local farmers willing to do additional activities or dedicated businesses such as airplane operators. Because they spread their equipment over more area, they may charge less than the cost that individual farmers would incur using their own equipment.

Argentinian and Brazilian farmers use custom operators more extensively than do US farmers (Meade et al. 2016). Their reported machinery and equipment costs are significantly lower than in the United States. Opportunities to reduce the expense of planting cover crops via custom operators may emerge.

Seeding Cooperatives. Some areas have developed seeding cooperatives that facilitate aerial seeding logistics for multiple farmers (North Jersey RC&D 2021). Cooperatives allow for economies of scale via the centralization of logistical challenges and third-party verification needed for some government programs and bulk seed buying discounts.

Equipment Sharing. Equipment sharing refers to a system where equipment is shared but no other activity is coordinated. Farmers use the shared equipment and then it is moved to another farmer to use. An example of equipment sharing is one farm using a combine in the summer to harvest small grains in the Plains states and then moving it to the Corn Belt to harvest coarse grains on another farm.

Equipment Modifications. Many full line agricultural equipment companies manufacture equipment that can be used to plant cover crops. Specialty companies are developing and modifying equipment to foster effective cover crop establishment.

Drone manufacturers are also developing technology that allows them to assist in cover crop seeding. A sample of specialty and drone equipment manufacturers is found in table 1.

Table 1
Sample of specialty and drone companies developing and manufacturing equipment that can be used for planting cover crops.

Manufacturers	Website
Specialty	
Gandy	https://www.gandy.net/product-categories/cover-crop-seeders
Great Plains	https://www.greatplainsag.com/en/products/9950/ts9100-turbo-seeder-attachment
Hiniker	https://agriculture.hiniker.com/cover-crop-seeders
MonTag	https://www.montagmfg.com/fortifier
Salford	https://salfordgroup.com/uses/cover-crop-seeding
Unverferth	https://www.unverferth.com/news/115/one-pass-cover-crop-planting-option
Drone	
DJI	https://ag.dji.com/smartfarm-web
EffortTech	https://www.effort-tech.com/cn/sp
Hylio	https://www.hyl.io

Note: The above listing of machinery manufacturers is a sample—not a comprehensive listing—and does not serve as an endorsement or recommendation.

SUMMARY AND CONCLUSIONS

Equipment constitutes the second largest cost of cover cropping. Machinery choice is integrated with several factors, including seed choice, cash crop decisions, weather, and more. Additionally, equipment availability may limit cover crop species selection. Expanding cover crop adoption will require innovation in machinery development and business arrangements.

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