Complementary Cover Crop Mixture

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Building a complementary cover crop mixture is a continuous process. An emerging concept is the importance of selecting cover crop species with functional complementarity rather than simply increasing the number of species. Based on this concept, selection of species in multi-mixes is based on different criteria: grower objectives/primary purpose of planting the cover crop, crop rotation and cropping system compatibility, above and belowground compatibility, complementarity of different ecosystem functions, compatibility with the growing environment, duration for cover crop growth, termination option(s) available, input/labour costs, planting equipment required, persistence/weediness, and potential net economic returns. Here, we propose a step-wise procedure to develop effective multi-species mixtures. The number of species and their ratio in the mixtures will depend on objective criteria, and hence long-term research is required to assess different species compositions and their impacts.

Keywords: cover crop ; sole cover ; multi-species mix ; crop rotation ; cropping system ; complementary mixture ; ecosystem functions

1. Introduction

Cover crops provide a range of well-documented benefits to growers and the environment. However, no single species can deliver all of these benefits, and hence planting mixtures is gaining increasing attention. Complementary cover crop mixtures can be considered as a key tool for enhancing the multi-functionality, resiliency, and sustainability of cropping systems in temperate North America. The benefits from multi-mix species depend on the selection of cover crop species based on the criteria: a summary of various services or characteristics of cover crops to enable multi-mix composition selection is provided (Table 1). The list below summarizes step-wise procedures that may be useful in developing cover crop mixtures considering the cash crop production system in Southwestern Ontario, Canada, as an example:

Table 1. Summary of various services and characteristics of cover crops to enable multi-mix composition selection (source: modified from Penn State Extension[1] and the Natural Resources Conservation Service, United States Department of Agriculture[2]).

Cover Crop Species	Selection Criteria/Services/Characteristics																					
	Seed Cost	Reduce Erosion	Increase Soil Carbon Biomass	N_2 fixation	Weed Suppression	Pest Suppression	Attract Pollinators	Reduce Subsoil Compaction	Recycle Nutrients	Broadcast Inter-seed	Rapid Growth	Living Mulch	N Retention	N Supply to the Following Cash Crop	Reduce Soil Diseases	Grazing/Forage Potential	Drought Tolerant	Flooding Tolerant	Shade Tolerant	Winter Hardiness	Weed Potential (Reseeding Potential)	Cash Crop Production and Profitability
Cool Season Grains																						
Cereal Rye (*Secale cereale* L.)	-	++	++		++				++	+	+		++	-	+	++	+	-	+	++	+	-/+
Oats (*Avena sativa* L.)	-	-	++		++	-/+			-	-	++	-	++	-/+	-	++		-				+
Warm Season Grains																						
Buckwheat (*Fagopyrum esculentum* L.)	-		-		++	-/+	++		++		++		+	+							++	+

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Sorghum/Sudan grass (*Sorghum bicolor* ssp. *bicolor* var. *sudanense*)	+	++	++		++	-/+		++	++		++		+	+	++	+	++	-				+
Legumes																						
Red Clover (*Trifolium pratense* L.)	+	[illegible]	+	[illegible]		-/+	+	+	+	++		-	+	++	[illegible]	+		-	+	+		+
Crimson Clover (*Trifolium incarnatum* L.)	+	+	+	+		-/+	+			++	-	-	+	++		++		+	+	-	++	+
Hairy Vetch (*Vicia villosa* Roth.)	+	-	++	++	+	-/+	+	-		+		-	+	++	-	-			-	+		-
Forage Pea/Austrian Winter Pea (*Pisum sativum* subsp. *arvense*)	+	+	+	++		-/+	+				+		+	++	+	+	-					+
Alfalfa (*Medicago sativa* L.)	+	+	++	++		-/+	+	++					+	++		++				+		+
Oilseeds																						
Forage Radish (*Raphanus sativus* L. var. *longipinnatus*)	+	+	-		++	-		++	++	+	+		+	-/+	+				-		-	+
Purple Top Turnip (*Brassica rapa* L. subsp. *rapa*)	+	+	+		++	+		++	++	+	+		+	-/+	+	-			-		-	+
Canola (*Brassica napus* L.)	++	+	+		-	+	++		+	+	+		+	-/+	++	-	+		-		++	-/+
Sunflower (*Helianthus annuus* L.)	++	+	+		-	+	++		-		+		+	-/+								-/+
Grasses																						
Annual Ryegrass (*Lolium multiflorum* Lam.)	-	++	++		++				++	++	+	+	++	+	-	++		+	+		++	+
Perennial Ryegrass (*Lolium perenne* L.)	-	++	++		+				++	++	+	+	++	+	-	++		+	+		+	+
Reliability: Above Average (++), Average (+), Below Average (-), and Blank = Not Recommended																						

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2. Step-Wise Procedures

Step 1: Identify the primary field crops or crop rotation system in which cover crops are to be introduced: for example, in Southwestern Ontario, two major cash crop rotation systems involve corn–soybean (CS) and corn–soybean–winter wheat (CSW) rotation systems[3][4]. Hence, appropriate cover cropping strategies involve frost-seeding into winter wheat in CSW, post-wheat cover crops in CSW, post-soybean cover crops in CS, and post-corn cover crops in CS or CSW rotation systems.

Step 2: Determine the time window or duration between the primary crop production cycles that is available for cover crop growth. For example, in Southwestern Ontario, winter wheat is harvested in late-July to early-August while soybean and corn are harvested in September–October (depends on location and varieties used) and hence the planting window for post-wheat cover crops starts from August till the following spring (March–April), while for post-soybean and post-corn cover crops, the planting windows are available from October to the following spring[3][4][5][6].

Step 3: List the cover crop species for which seeds are potentially available in the region: Table 1 summarizes potential cover crops available in Southwestern Ontario, and their associated benefits. Some additional crops that can be used as cover crops in the region include soybean, lentil, sweet clover, pearl millet, wheat, triticale (x *Triticosecale*)[1].

Step 4: Narrow down the list of candidate cover crops by considering the criteria discussed in Table 1. Those involve objectives or services required as well as strengths and weaknesses of each cover crop species in terms of planting date, environmental suitability, seed cost and availability, complementary growth periods and growth habits, nutrient acquisition strategies, and option(s) available for cover crop termination, etc. Priority should be given to over-wintering species (e.g., cereal rye, clovers) as post-soybean or post-corn cover crops due to a narrower window available for fall growth[1].

Step 5: Develop mixtures (e.g., 2 species or higher) by considering the number of species included in the mixture, seed size, planting method (no-till drilling or broadcast), and competitiveness of selected species. For example, a potential post-wheat two-way mixture may involve oats (or cereal rye) + oilseed radish, or oats + winter pea (or hairy vetch). Also, a potential three-way multi-mix may involve oats, red clover (or winter pea) and radish while a 10 way mix can involve the cool season grains (e.g., oats, cereal rye), warm-season grains (e.g., buckwheat, sorghum Sudan), legumes (e.g., clover, hairy vetch, winter pea), and oilseeds (e.g., radish, turnip, sunflower or canola)[4]. Post-corn or post-soybean cover crops may involve cereal rye or annual ryegrass as sole covers or mixed with clover[4]. While developing the mixture, one of the methods to determine the mixing ratio involves dividing the recommended seeding rate for each species by the number of species in the mixture[7][8].

Step 6: Plant a cover crop or a mixture at the appropriate time. A common strategy is to plant winter cover crops following the cash crop harvest in the early fall (e.g., post-wheat, -corn or -soybean) to utilize residual moisture. To avoid volunteer crops, it may be better to wait for a few days/weeks following the winter wheat harvest, allow the leftover seeds to germinate, and then terminate them using appropriate control measures, followed by planting the cover crop mixture. Alternatively, some cover crops (e.g., annual ryegrass) can be inter-seeded/drilled between rows of corn during the V7-V8 growth stage of corn or can be inter-seeded (e.g., cereal rye) into corn one month after silking (i.e., Kernel Dent Stage or R5 stage). Similarly, cereal rye can be inter-seeded into soybean at leaf yellowing to 50% leaf drop stage. Also, red clover can be inter-seeded or frost-seeded into winter wheat during early spring (e.g., March–April) in temperate North America[9][3][10][4].

Step 7: It is important to terminate cover crops at the correct time. Some options include fall termination by using a mouldboard plow/chisel or let them stay on the soil surface over winter, or termination in the spring using herbicides followed by no-till or strip-till planting[4][11][12][13]. Better quality biomass (with a lower C:N ratio in cereal cover crops) can be obtained when these cover crops are terminated while green. This strategy further prevents cereal covers from producing seeds that could become weeds in the following season.

Step 8: Building an appropriate cover crop mixture is a continuous process. Species composition may vary between years and location (soil types, moisture conditions, etc.), which may affect functional diversity/multifunctionality of cover crop mixtures[14][4], and therefore, continuous observation of the species composition and associated ecosystem services is suggested along with any needed adjustment(s) in the species mix.