United States Department of Agriculture

FINAL STUDY REPORT (March 2024)
Lockeford Plant Materials Center
Lockeford, CA

Termination Timing for Cover Crops Using a Roller Crimper in California's Central Valley - One Year Demonstration Results

Annie Edwards and Margaret Smither-Kopperl

Roller crimpers are used to terminate cover crops in some areas of the United States. The successful use of roller crimpers can reduce pesticide use and ground disturbance in cropping systems. While some innovative Californian farmers use roller crimpers to terminate cover crops, knowledge gaps remain and hinder the wider implementation of this tool. The Lockeford Plant Materials Center (CAPMC) sought to determine the optimum growth stage to terminate four cool season cover crops and mixtures commonly used in orchards with a tractor-mounted roller

crimper in a demonstration planting. After one season of data collection in an unusually wet and cold winter, the most successful crimping/termination was after flowering and just before seed set. Greater success in termination was noted with the brassica mix and fava beans, compared to the cereals, which continued to grow after crimping, even at the latest termination date when the cereals were heading out.

INTRODUCTION

The CAPMC evaluates innovative management practices at the request of local producers and NRCS staff. Using a tractor-mounted roller crimper to terminate cover crops is a relatively new practice in California cropping systems. A roller crimper is a drum or cylinder, often with blunt curved blades, that is rolled over cover crops to injure crop stems, stop further growth and produce a thick, weed-suppressing mat of cover crop biomass (Hoorman, 2020). Roller crimper cover crop termination can have multiple benefits, including reducing pesticide use, decreasing hot summer soil temperatures, conserving soil moisture, decreasing erosion, and increasing soil organic matter (Ashford & Reeves, 2003; Kornecki et al., 2009; Mirsky et al., 2009). While roller crimper termination timing has been studied in the Midwest, Mid-Atlantic, and South (Jani et al., 2015; Silva & Delate, 2017; Wallace et al., 2017), it has been minimally researched in California agriculture. Further, the research that has been conducted reported poor crop stands for trials on cotton, tomato, eggplant, and cowpea after roller crimping (Luna et al., 2012). Despite this, an experimental walnut farmer in the northern Central Valley has successfully used a roller crimper to terminate cover crops in an orchard setting, the targeted agricultural system of this study (Center for Regenerative Agriculture and Resilient Systems, 2019). The CAPMC aims to demonstrate the optimal timing for roller crimper termination with common orchard cover crops for California's Central Valley.

In previous evaluations at the CAPMC, successful roller crimper termination has been difficult due to inexact timing. When terminated too early, cover crop stems are not sufficiently injured, continue to grow, and do not provide a soil cover or mat. Alternatively, late termination can provide a vegetative mat but can also result in cover crop seed production, depending on the plant's vegetative stage and the degree of stem injury. Cover crop seed production is generally viewed as a nuisance depending on the goals of the cropping system. However, if a producer intends to replant cover crops the following year, some cover crop volunteering in subsequent years could be perceived as beneficial.

MATERIALS AND METHODS

The CAPMC is located on the eastern side of the San Joaquin Valley and sits on the historical floodplain of the Mokelumne River in Major Land Resource Area (MLRA) 17. The roller crimper termination demonstration was established during the 2022-23 growing season on a Vina fine sandy loam with a slope of 0-2% at an elevation of 66 ft. Previous field management consisted of mowing to minimize resident vegetation seed set. The field was disked and cultipacked prior to planting. The demonstration was drill seeded with a Great Plains Cone Seeder (Great Plains Ag, Salina, KS) into plots approximately 300 feet long by 5 feet wide with 9 rows at 7-inch spacing on November 16, 2022. Seeding rates varied depending on species (Table 1), with target seeding rates for this study adjusted to reflect industry standard rates (Clark, 2008). Refer to the CAPMC Cover Crop Chart for more guidelines on seeding rates and planting cover crops in California (Smither-Kopperl, 2018). Seed was purchased from Kamprath

Seed, Manteca, CA, and reflects commonly used cool season cover crop species and mixes in the area. The demonstration was not fertilized, irrigated, or grazed, and there was no method of weed control during the demonstration.

Table 1: Seeding mixes, species, and rates used in the cover crop termination demonstration at the CAPMC (2022-2023).

Mix	Species	% Mix	Target Seeding Rate (lb/ac)	Actual Seeding Rate PLS (lb/ac)	Actual Seeds/ft²
Faba Bean	Faba Bean	***100%***	80 to 100	***97.2***	***6.69***
Spring Triticale	Spring Triticale	***100%***	50 to 75	***49.6***	***13.66***
Brassica Mix	Canola	25%		2.83	6.50
	White Mustard	20%		2.26	5.19
	Yellow Mustard	15%		1.7	3.90
	Daikon Radish	20%		2.26	1.56
	Common Yellow Mustard	20%		2.26	5.19
	Total	***100%***	8 to 12	***11.3***	***22.33***
Annual Plow Down (APD) Mix	Faba Bean	45%		38.84	2.67
	Field Peas	35%		30.21	1.66
	Common Vetch	10%		8.63	1.58
	Cayuse Oats	10%		8.63	3.82
	Total	***100%***	100	***86.3***	***9.74***

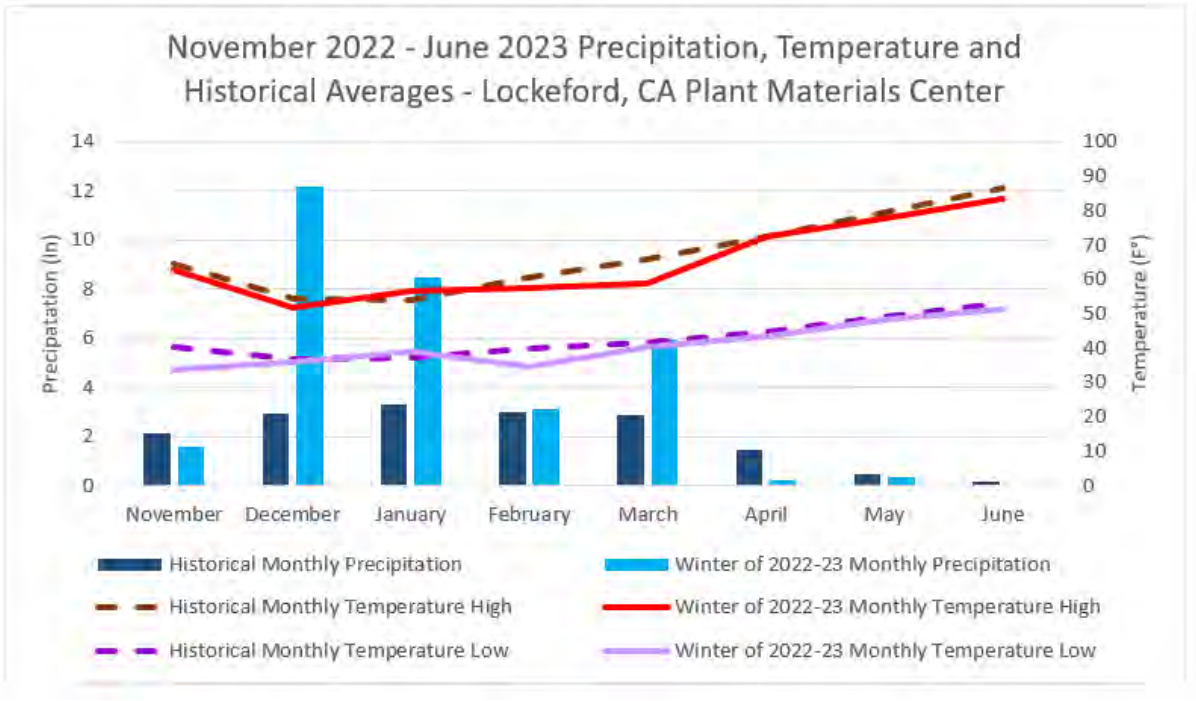

Figure 1. Mean minimum and maximum temperatures during the 2022/2023 growing season. Total precipitation doubled the historical average between November 2022 and March 2023 and low temperatures were generally lower than the average. Monthly weather data from November through June was provided from Western Weather Group Lockeford Weather Station. Average weather summaries from 1893-2015 for the Lodi area were provided from Western Regional Climate Center.

CAPMC experienced extreme rainfall during the demonstration growing season. While the historical average (1893-2015) precipitation between November and March is 14.2", the recorded precipitation during the winter of 2022-2023 was 31.3" (Figure 1). Further, temperature highs were below the historical average (1893-2015) during February and March. Due to the cold, wet weather, plant growth and maturation were delayed compared to an average year.

The demonstration plots were organized into six blocks, each with a different termination date (Figure 2). The blocks included all four cover crop treatments: spring triticale (×*Triticosecale* Wittm. ex A. Camus [*Secale* × *Triticum*]), fava bean (*Vicia faba*), Project Apis m. (PAm) Pollinator Brassica mix including canola (*Brassica napus*), white mustard (*Sinapis alba*), yellow mustard (*Brassica juncea*), daikon radish (*Raphanus sativus*) and common yellow mustard (*Sinapis alba*), and Annual Plow Down mix (APD) including fava bean (*Vicia faba*), field pea (*Pisum sativum*), common vetch (*Vicia sativa*) and Cayuse oats (*Avena sativa*).

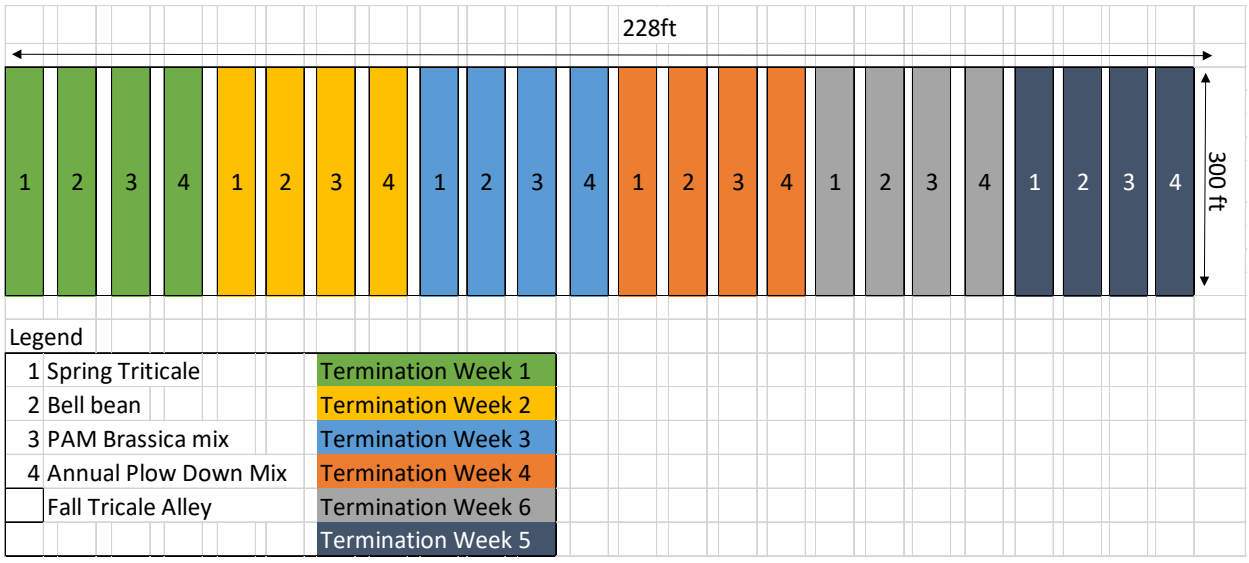

Figure 2. Plot map for the roller crimper termination demonstration. The blocks are distinguished by color and are associated with different termination dates.

Termination of cover crop blocks was planned in week increments. However, the cold, wet spring slowed plant growth and resulted in a 3-week gap in termination events after the first three blocks were terminated.

Average height, vegetative stage, canopy cover, and biomass production data were collected from three evenly spaced points per cover crop entry in the "Termination Week 6" block (Figure 2) for the entire trial. Data was collected from the "Termination Week 6" block as it was the last block to be crimped and thus could have data collected from it for the longest period. To avoid edge effects, "Termination Week 6" plots were located between "Termination Weeks 4 & 5". Regrowth and "bounce-back" data were taken after all plots were terminated.

Plant height, from the base to the tallest point, is reported as an average from three representative plants at three representative locations per plot. The vegetative stage was recorded according to the Plant Materials Center's protocol *Growth Stages and Descriptions of Forbs, Legume and*

Small Grains (2021). For the APD mix, the stage of the fava beans was recorded to represent the mix. Fresh weight of aboveground biomass (FWAB) was defined as the above-ground accumulation of plant growth, taken from ground level. For this procedure, biomass was collected as close to the ground as possible, leaving no more than ¼ inch stubble height. These measurements were collected by randomly placing a square foot quadrat in the plot and collecting the aboveground biomass that fell within the square foot perimeter. Weeds were excluded. After weighing and recording the FWAB, the samples were dried to constant weight in a drying oven and recorded as dry matter weight (DM). Canopy cover photos were taken on each data collection date to assess the percent cover. These photos were processed with Foliage software from Canopeo (Patrignani, 2020), which analyzes green canopy cover to determine the percent cover.

Regrowth and "bounce back" data were taken after all plots were terminated. Regrowth was visually assessed and recorded if plants exhibited damage from the roller crimper, but either resprouted or continued to grow from a section of the plant that was less damaged. "Bounce back" occurs when uninjured plant stems return to an upright position after a roller crimper tractor pass (Figure 3 and 4). "Bounce back" was visually assessed and recorded if a significant number of plants were standing. Regrowth and "bounce back" data were collected one week after the final crimping treatment.

Figure 3. Oats displaying "bounce back" among legumes that remained crimped.

Figure 4. Cereal grasses displaying "bounce back" as they lift to a 45° angle right after crimping.

RESULTS AND DISCUSSION

California has a Mediterranean climate, which is highly variable from year to year, with respect to temperature and precipitation. During the 2022-2023 winter cover crop growing season, due to cold and wet conditions, crops in the region were delayed by three weeks compared to an average year and five weeks compared to the previous year.

Height

From March 27th onward, the brassica mix was the tallest treatment. By the last termination date and at their tallest recorded height, the brassica mix reached an average of 46.5 in, followed by fava beans (41.73 in), the spring triticale (39.37 in), and lastly the APD mix (31.89 in). The most successful termination crimping occurred at the latest termination date on the tallest plants.

Vegetative Stage

The brassica mix both regrew and bounced-back when first recorded at their flowering to seed maturing stage, April 15th, indicating they either needed to further develop in this stage or other factors that changed during this period, such as height, needed to increase. About one week into their flowering to seed maturing stage, the brassica mix stopped bouncing-back and regrowing. APD and the fava bean treatment remained crimped after the fava beans in this mix reached the R3 stage. R3 is when the fava beans have visible early pods with pods reaching ~ 3/16". The fava beans in the APD mix slightly lagged in stage behind the single fava species treatment, indicating that competition from proximity to other species in the mix slowed development. Lastly, the triticale stopped regrowing once it reached stage 10.5, where it started to flower. The vegetative stages that resulted in the most successful roller crimper termination for each treatment are summarized in Table 2.

Table 2. Plant stage with highest success of being terminated by the roller crimper. Success was determined by resulting in the least "bounce back" and regrowth.

SEED MIX	***ANNUAL PLOW DOWN MIX***	***FAVA BEANS***	***BRASSICA MIX***	***SPRING TRITICALE***
STAGE	R2 – R5 (legumes)	R2 – R3	flowering to seed maturing	10.5

Biomass

Biomass was collected at the 2nd, 3rd, and 6th scheduled termination events. By the last termination date, fava beans produced the most biomass, averaging 32,060 lb./ac DM (Table 3). The second highest biomass production came from the APD mix with 16,727 lb./ac DM, followed by spring triticale with 7,841 lb./ac DM, and then the brassica mix with 5,314 lb./ac DM. Biomass production was likely not a driving factor of successful termination as the brassica mix with the lowest biomass production resulted in a more successful crimping. Lower biomass production is also not attributable to a more successful crimping as the triticale treatment produced the second least biomass and was the most unsuccessful crimping.

Table 3. Growth of four cover crop mixes from March 7 – May 9, 2023, as measured by height, growth stage, fresh weight aboveground biomass (FWAB), and above ground dry matter (DM).

Treatment	Data Collected	3/7	3/13	3/20	3/27	4/4	4/25	5/2	5/9
Annual Plow Down Mix									
	Height[1]	5	5.8	7.4	7.2	9.4	24.1	26.8	32
	Stage[2]	V5-6	V4-6	V6	V7-8	R1-2	R2	R3	R2-5
	FWAB[3]				26,387	23,435			85,378
	DM[4]				3,746	3,223			16,727
Fava Bean									
	Height	5.4	6	8.2	11.3	14.9	33.6	40.7	41.8
	Stage	V5-7	V6-8	V6-7	V8-9	V7-R1	R2	R2-3	R4-5
	FWAB				36,765	37,810			211,005
	DM				4,182	4,704			38,333
Brassica Mix									
	Height	2.5	3.6	8	12.4	17.4	37.5	42.6	46.4
	Stage	rosette to stem growth	rosette to stem growth	stem growth to budding	stem growth to flowering	stem growth to flowering	flowering to seed maturing	flowering to seed maturing	seed maturing
	FWAB				6,970	11,413			14,461
	DM				697	1,568			5,314
Spring Triticale									
	Height	5.1	5.5	8	10.2	11.9	21.9	25.9	39.3
	Stage	3	3	3-4	4-5	6-7	10	10.1	10.5
	FWAB				6,011	7,057			16,814
	DM				958	1,655			7,841

[1] Height is recorded in inches (in)
[2] Stage was based on Growth Stages and Descriptions of Forbs, Legume and Small Grains
[3] Fresh weight aboveground biomass (FWAB) is recorded in pounds per acre (lb./ac)
[4] Dry matter (DM) is recorded in pounds per acre (lb./ac)

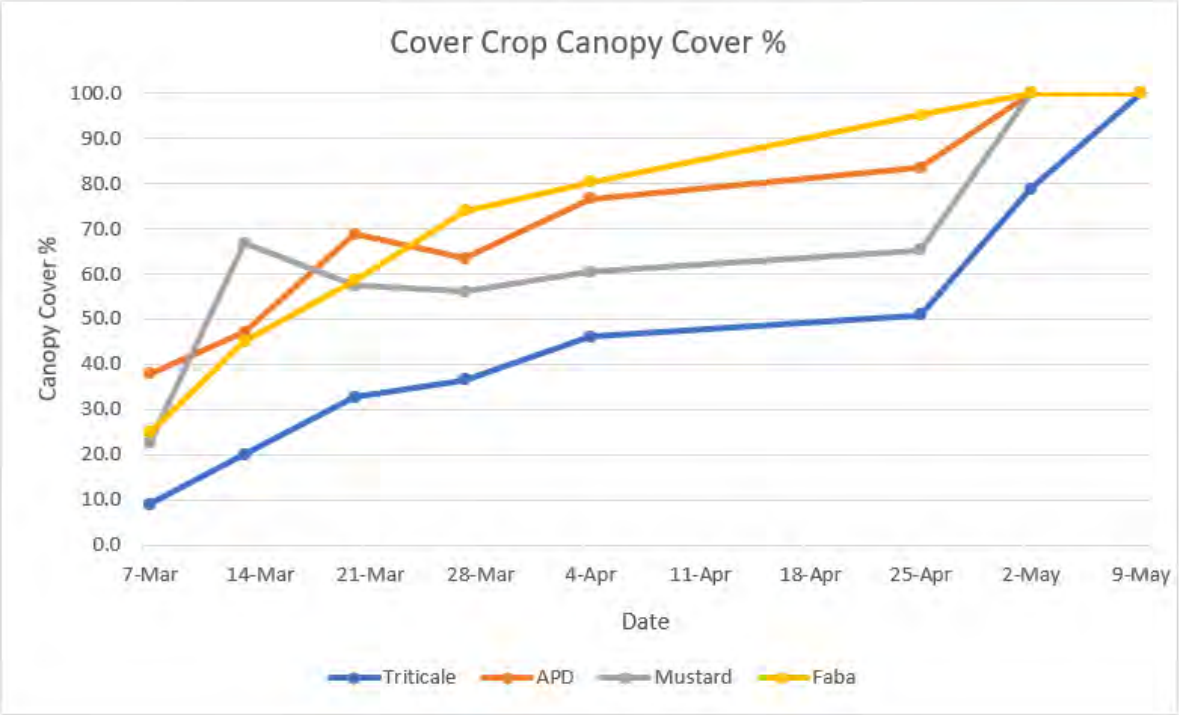

Figure 5. Percent canopy cover between March 7th and May 9, 2023, in the roller crimper termination demonstration plots at the CAPMC.

Canopy Cover

As expected, canopy cover steadily increased for all cover crop treatments over the course of the demonstration. The APD mix, brassica mix, and fava beans all reached 100% canopy cover by May 2nd, while the triticale treatment only lagged by a week, reaching 100% canopy cover by May 9th (Figure 5 and 6).

"Bounce back"

"Bounce back" did not occur in the brassica mix or fava beans after the May 2nd termination date (Table 4). The APD mix continued to exhibit insufficient stem crimping ("bounce back") until the May 9th treatment, and all triticale termination treatments resulted in "bounce back". As a metric of a successful crimping, the triticale treatment was never successfully crimped in this nonreplicated demonstration.

Figure 6: Fava bean canopy cover showing one foot quadrat.

Regrowth

Like "bounce back", regrowth is used as a measure of success in this experiment. The brassica mix did not have any regrowth after May 2nd, while fava beans and triticale stopped regrowing after May 9th (Table 4). Unusually, APD did not have regrowth on May 2nd but did after May 9th. This regrowth is likely due to 0.32" of rain between May 2nd and 6th. This was the only rain Lockeford received in the month of May. Note, that this study does not capture any regrowth that could have resulted from seed produced by these cover crops in the following season.

Table 4. "Bounce-back" (BB) and regrowth (RG) results from the trial. All data was taken on May 15, 2023, about a week after the final crimping. 1 represents the presences of the trait, while 0 indicates the absence. Fava beans and triticale are indicated as having 0 "bounce back" on March 20th because they were mowed.

Crimping Date	***20-Mar***		***27-Mar***		***4-Apr***		***25-Apr***		***2-May***		***9-May***	
Data	RG	BB	RG	BB	RG	BB	RG	BB	RG	BB	RG	BB
Annual Plow Down Mix	1	1	1	1	1	1	1	1	0	1	1	0
Fava Bean	1	0	1	1	1	1	1	1	1	0	0	0
Mustard	1	1	1	1	1	1	1	1	0	0	0	0
Triticale	1	0	1	1	1	1	1	1	1	1	0	1

In this demonstration, most plots were not successfully terminated by the roller crimper, evident by plants "bouncing back" and/or regrowing after being crimped. The only plots where neither "bounce back" nor regrowth occurred were the brassica mix treatments during its last two crimpings and the fava bean treatment in its final crimping. Grass species had a high rate of "bounce back". The triticale quickly recovered after being crimped, and the oats in the APD mix recovered while the legumes remained down after being crimped (Figure 7). The brassica mix formed a mat when crimped (Figure 8). The fava beans, while lying flat after having their fleshy stems crimped (Figure 9), did not cease growth, rather, the end of the fava beans turned up and continued to grow (Figures 10 and 11).

Figure 7. Annual Plow Down Mix after being crimped at the R3 stage.

Figure 8. Brassica mix one month after being crimped at the seed maturing stage.

Figure 9. Fava bean treatment right after being crimping during the R2 stage.

Figure 10. Fava bean regrowth one week after roller-crimping.

Figure 11. Close-up of the crimped stems continuing to grow.

CONCLUSION

The most successful treatment in this roller crimper termination demonstration was the brassica mix after flowering and fava beans after the early visible pod stage. The least successful were the cereals, triticale and oats in the annual plow down mix, which exhibited the most "bounce back" and regrowth.

Overall, our results found that roller crimping may be a viable cover crop termination method in orchards if planting a brassica mix or fava beans and terminating at the right time. Due to only one year of data collection and an unusually wet and cold spring, termination dates from this demonstration should not be extrapolated for specific use. Further, these climate anomalies exemplify that plant stage is a more reliable termination date metric than calendar date.

The next steps may include testing different seeding rates of these species and mixes to determine their impact on roller crimping or to have a multi-year trial to understand the nuances of these results and if they are repeatable.

LITERATURE CITED

Ashford, D. L., & Reeves, D. W. (2003). Use of a mechanical roller-crimper as an alternative kill method for cover crops. *American Journal of Alternative Agriculture*, *18*(1), 37–45. https://doi.org/10.1079/AJAA2003037

Center for Regenerative Agriculture and Resilient Systems. (2019). Daniel Unruh [California State University, Chico]. *Farmer Mentors & RA Demos*. https://www.csuchico.edu/regenerativeagriculture/demos/daniel-unruh.shtml

Clark, A. (2008). *Managing cover crops profitably* (3rd ed.). Diane Publishing.

Hoorman, J. (2020, May 18). Roller Crimping Cover Crops [Ohio's Country Journal]. *Crimping Cover*

Crops. https://ocj.com/2020/05/crimping-cover-crops/
Jani, A. D., Grossman, J., Smyth, T. J., & Hu, S. (2015). *Winter legume cover-crop root decomposition and N release dynamics under disking and roller-crimping termination approaches*.
Kornecki, T. S., Price, A. J., Raper, R. L., & Arriaga, F. J. (2009). New roller crimper concepts for mechanical termination of cover crops in conservation agriculture. *Renewable Agriculture and Food Systems*, *24*(3), 165–173. https://doi.org/10.1017/S1742170509002580
Luna, J. M., Mitchell, J. P., & Shrestha, A. (2012). Conservation tillage for organic agriculture: Evolution toward hybrid systems in the western USA. *Renewable Agriculture and Food Systems*, *27*(1), 21–30. https://doi.org/10.1017/S1742170511000494
Mirsky, S. B., Curran, W. S., Mortensen, D. A., Ryan, M. R., & Shumway, D. L. (2009). Control of Cereal Rye with a Roller/Crimper as Influenced by Cover Crop Phenology. *Agronomy Journal*, *101*(6).
Patrignani, A. (2020). *Foliage (Version v1.0)*.
Plant Materials Program. (2021). *Growth Stages and Descriptions of Forbs, Legumes, and Small Grains*.
Silva, E. M., & Delate, K. (2017). A Decade of Progress in Organic Cover Crop-Based Reduced Tillage Practices in the Upper Midwestern USA. *Agriculture*, *7*(5), 44. https://doi.org/10.3390/agriculture7050044
Smither-Kopperl, M. (2018). *Cover Crop Chart: Common Cover Crops for California*. https://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/capmctn13333.pdf
Wallace, J. M., Williams, A., Liebert, J. A., Ackroyd, V. J., Vann, R. A., Curran, W. S., Keene, C. L., VanGessel, M. J., Ryan, M. R., & Mirsky, S. B. (2017). *Cover Crop-Based, Organic Rotational No-Till Corn and Soybean Production Systems in the Mid-Atlantic United States*.