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Lockeford Plant Materials Center, Lockeford, CA

ADAPTATION OF LENTIL CULTIVARS AS COVER CROPS IN CALIFORNIA'S CENTRAL VALLEY

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ABSTRACT

Several commercially available lentil cultivars were evaluated at the NRCS California Plant Materials Center (CAPMC) in Lockeford, CA during the 2015/2016 growing season. The objective was to assess lentils as a potential cover crop in California's Central Valley. Canopy cover was the only data where statistically significant differences between lentil cultivars were found (P<0.05). Other evaluations were not significantly different from one another, but did show numerical trends. These evaluations included germination and field emergence, plant height, disease and insect resistance, aboveground biomass, and nitrogen content. Results indicate that lentil cover crops, depending on cultivar, may help reduce additional nitrogen fertilizer inputs through nitrogen fixation and biomass contributions. Due to their short height, these lentil cultivars would be a low frost risk in orchards and vineyards. They also appear to be fairly resistant to disease and insect damage in this area of the Central Valley. However, these lentil cultivars did not perform well under a high weed pressure situation and are not recommended in areas that have a history of high weed pressure. Further evaluations need to be conducted at the CAPMC on several of these lentil cultivars to recommend the best adapted for California agricultural operations.

INTRODUCTION

Lentils are increasing in popularity as a cover crop option and rotation crop with cereal grains in the Northwestern United States and Canada. Lentils are a low growing (1 - 2.5 ft. height) cool season, annual legume (Cash et al., 2001). They are resistant to high temperatures and drought conditions, which makes them a potential alternative cover crop for California's Central Valley. Lentils are also very frost tolerant, decompose quickly due to the low C:N ratio, and if inoculated with the proper *Rhizobum* bacteria, are capable of fixing 30 – 100 pounds atmospheric nitrogen per acre (Pavek et al., 2016). In a study conducted by Allen et al. in 2001, lentil green manure maintained water productivity and offset nitrogen fertilizer requirements after six years, compared to a traditional wheat-fallow rotation.

The use of a legume, such as lentils, in rotation as a cover crop has several agronomic and soil health benefits. Using lentils as a rotation crop can help to break pest cycles, since it is not a host for cereal disease pathogens, and it can disrupt problem weed cycles (Pavek et al., 2016). Other general benefits of using cover crops include increased soil organic matter, water holding capacity, and available nutrients. However, there can be drawbacks to lentil cover crop use if they are not managed properly. Lentils may deplete soil moisture if not terminated before pod set and they are not very weed competitive, both of which can be a problem in California.

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A lentil cultivar was observed to out-perform 22 other legumes in a demonstration cover crop planting at the CAPMC during the extreme drought year of 2013/2014, where the total precipitation was 8.1 inches, which included 2 inches of rainfall from June to December of 2014 (California Irrigation Management Information System, 2016). The objective of this study was to evaluate the adaptation of lentil cultivars as a potential cover crop in California's Central Valley. During 2014/2015 a demonstration planting of single plots was established and evaluated. During the 2015/2016 growing season the growth characteristics and production attributes of the six best performing commercially available lentil cultivars were evaluated in a replicated trial for adaptation and performance in California. Results from these trials will advise NRCS field offices and the public on alternative cover crop options, as well as location and farming operation suitability. This data will be used to focus on specific lentil cultivars for testing in future drought tolerant cover crop studies at the CAPMC and other locations.

MATERIALS AND METHODS

The adaptation trial was conducted at the CAPMC in Lockeford, California. The CAPMC is located on the eastern side of the San Joaquin Valley in central California and sits on a historical flood plain on the east bank of the Mokelume River. The site soil series is a Vina fine sandy loam, on 0 to 2 percent slopes. It is a very deep, well-drained soil with pH ranging from slightly acid or slightly alkaline. The average annual maximum temperature in this area is 73.6°F and minimum temperature is 46°F. The average annual precipitation is 17.24 inches, mainly occurring between the months of December and March (NOAA, 2016). Total precipitation between Sept 1, 2014 and March 31, 2015 was 10.3 inches, with 6.5 inches falling in December of 2014 (California Irrigation Management Information System, 2016). Total precipitation between October 1, 2015 and June 28, 2016 was 16.7 inches (NOAA, 2016).

Ten lentil cultivars were provided by ARS Legume Breeding Program in Pullman, WA with the assistance of the Pullman PMC. These were 'Avondale', 'Brewer', 'Cedar', 'Merrit', 'Morton', 'Pennel', 'Richlea', 'Riveland', 'Shasta', and accession LC06601734L. Three additional lentil cultivars, 'Viceroy', 'CDC-KR1' and 'CDC Impower', were supplied by Kamprath Seed in Manteca, CA.

The 2014/2015 demonstration plot was planted across the center of Field 6 running from north to south onto an area previously planted in barley. The area was disked and cultipacked prior to planting and the seed was planted into 4 x 25 foot plots using a Planet Junior push planter on November 12, 2014. The seeding rate for the ten cultivars from Pullman was the recommended rate of 10 seeds per square foot, but the additional three lentil cultivars were planted at a higher rate. Weeds were controlled by cultivation using a wheel hoe between rows. Biomass from 1 foot square was collected from a representative area of the plot at 50% bloom in April 2015.

The 2015/2016 trial was conducted on the north end of Field 6 at the CAPMC, which was previously planted in oats and winter pea. The area was disked and cultipacked prior to planting. The trial was a randomized complete block design with four replications running from east to west. Plots were 10 foot long by 5 foot wide and were broadcast seeded on October 13, 2015. Six different lentil cultivars, including 'Richlea', 'Pennell', 'Merrit', 'Cedar', 'Shasta', and 'Brewer' from the ARS Legume Breeding Program in Pullman, WA were evaluated during the 2015/2016 growing season (Table 1). These cultivars were chosen for their drought resistance and biomass yield during the 2014 demonstration planting (Figure 1). The performance indicated a need for further evaluation of lentils as a cover crop option in the Central Valley.

Table 1. Seeding rates by lentil cultivar in the 2016 trial at the Lockeford PMC.

Cultivar	(PLS lbs/acre)
Brewer	80
Cedar	50
Merrit	80
Pennell	80
Richlea	65
Shasta	65

Table 2. Biomass yield of lentil cultivars in 2015 and 2016 at the Lockeford PMC.

Biomass Means across Lentil Cultivars		
Cultivar	2015	2016
	---lbs/acre---	
Avondale	7082	N/A
Brewer	21246	9426
Cedar	26305	22818
LC06601734L	6070	N/A
Merrit	18211	14002
Morton	4047	N/A
Pennell	16187	18333
Richlea	19222	18009
Riveland	10117	N/A
Shasta	9105	13499
CDC Impower*	20235	N/A
CDC KR-1*	17199	N/A
Viceroy*	40470	N/A

*Planted at a higher seeding rate.
Several cultivars were not evaluated in 2016.

Weed pressure in the plots was extremely high in 2016 due to some precipitation after three years of severe drought in California. Weeds that were prevalent in the plots included shepherd's-purse (*Capsella bursa-pastoris*), little mallow (*Malva parviflora*), prickly lettuce (*Lactuca serriola*), ripgut brome (*Bromus diandrus*), henbit (*Lamium amplexicaule*), and sowthistle (*Sonchus spp.*). There were also volunteers from other species plots including oats, vetch and field peas.

Several evaluations were collected during the 2015/2016 growing season following the national cover crop adaptation trial protocol, including: germination/field emergence, canopy cover, plant height, bloom date, disease and insect resistance, aboveground biomass, and nitrogen (N) content. Germination/field emergence was defined as how well the species germinated and emerged after planting. Germination/emergence were evaluated 21 days after planting on a 0 - 3 scale, where 0 = poor (<25% germination), 1 = moderate (30 - 60% germination), 2 = good (65 - 85% germination), and 3 = excellent (90 - 100% germination). Canopy cover was a visual estimate of the percentage of ground covered by the seeded species. Plots were evaluated 101 days after planting and 195 days after planting.

Evaluations were based on a 1 - 5 scale where 1 = 1% - 20% canopy cover, 2 = 21% - 40% canopy cover, 3 = 41% - 60% canopy cover, 4 = 61% - 80% canopy cover, and 5 = 81% - 100% canopy cover. Results were then multiplied by 19 to transpose the rating to a percentage. Plant height was defined as the average height of lush canopy growth. Plant height was collected from three random locations within each plot. Bloom date was defined as the date of 50% bloom in the lentils. It indicates the optimum nitrogen content in the aboveground biomass and was also the termination date of the cover crop. Disease and insect resistance was a visual estimate of the resistance to foliar diseases and insect damage. Plots were rated on a 0 - 5 scale, where 0 = no damage and 5 = severe damage. Some symptoms of damage on lentil cultivars included brown specking and holes in leaves. Aboveground biomass was defined as the amount of aboveground accumulation of plant growth taken at ground level at 50% bloom. A square foot area was harvested from each plot from a representative area and then weighted. Biomass was then converted from grams per square foot to pounds per acre. N content was defined as the nitrogen concentration in the aboveground portion of the biomass and expressed as a percent. Composite biomass samples were dried and weighed to get a dry matter determination for dry matter yield and sent to a lab for analysis. Total nitrogen yield was calculated using the percent dry matter yield and N content.

Statistical analysis was run on the evaluations collected from the 2016 trial using Statistix 8 software. Analysis of variance (AOV) was run on a randomized complete block (RCB) along with Tukey's 1 Degree of Freedom test for non-additivity to determine if there were any statistically significant differences between cultivars at the 5% level of probability (P = 0.05). A mean separation test was also performed on the canopy cover data to determine which cultivars were significantly different from one another.

a.'Brewer' Lentil | b. 'Cedar' Lentil

Figure 1. Photos of lentil cultivar demonstration plots at the Lockeford Plant Materials Center on 4/20/15.

c. 'Merrit' Lentil

d. 'Pennell' Lentil

e. 'Richlea' Lentil

f. 'Shasta' Lentil

Figure 1. Photos of lentil cultivar demonstration plots at the Lockeford Plant Materials Center on 4/20/15.

RESULTS AND DISCUSSION

During the 2014/2015 trial, the lentils grew well, even though it was a very dry season (Figure 1). There were substantial differences in biomass between the cultivars. Viceroy had the highest biomass, but was one of the cultivars planted at a high seeding rate so was not included in the selection of best cultivars for trial the following year. (Table 2).

During the 2015/2016 trial, canopy cover evaluations were the only data sets where statistically significant differences between lentil cultivars at the 5% level of probability were found (Table 4). All other cultivar evaluations, including germination/field emergence, plant height, disease and insect resistance, aboveground biomass, and N content were not significantly different from one another, but some did show numerical trends (Table 3).

Table 3. Evaluation means across six lentil cultivars at the Lockeford PMC in 2016.

Evaluation Means across Lentil Cultivars (2016)							
Cultivar	Germ/Emerg 21 DAP (0-3)*	Height (in)	Aboveground Biomass (lbs/acre)	Disease Resistance 101 DAP (0-5)**	Disease Resistance at Termination (0-5)**	Insect Resistance 101 DAP (0-5)**	Insect Resistance at Termination (0-5)**
Brewer	0.50	12.75	9426	0	1.0	0	1.0
Cedar	0.25	12.25	22818	0	1.0	0	1.0
Merrit	0.25	12.50	14002	0.25	1.0	0.25	1.0
Pennell	0	13.25	18333	0	0.75	0	1.0
Richlea	0.50	11.63	18009	0	1.0	0	1.0
Shasta	0.25	11.68	13499	0	0.68	0	0.67

Means within columns were not significantly different as determined by least significant difference test at P<0.05.
* Rated on a 0 - 3 scale, where 0 = poor germination (<25%), 1 = moderate (30 - 60%), 2 = good (65 - 85%), and 3 = excellent (90 - 100%)
** Rated on a 0 - 5 scale, where 0 = no damage and 5 = severe damage.

Germination/emergence was the first evaluation to be collected at 21 days after planting (11/3/15). This evaluation is useful for cultivar comparison and is an indicator for quick establishment for soil protection and early weed control. ‘Richlea’ and ‘Brewer’ were the two cultivars with the highest germination and field emergence at this stage, followed by ‘Cedar’, ‘Merrit’ and ‘Shasta’ (Table 3). ‘Pennell’ was not observed to have emerged by this date (Table 3). These results indicate that ‘Richlea’ and ‘Brewer’ may be more competitive for winter weeds and establish faster than the other cultivars, which could be useful if soil erosion is a concern. ‘Pennell’ was much slower to emerge (emerged after 21 DAP) indicating that it would be less competitive with winter weeds.

Plant height was evaluated at 195 DAP, which was also the termination date (4/25/16). Plant height information was used for cultivar comparisons, its relation to aboveground biomass, and frost potential. None of the height measurements between cultivars were significantly different from one another (Table 3). All evaluations were within the 1 foot range, which would be a low risk for frost potential in orchards and vineyards.

Disease and insect resistance were evaluated at 101 DAP (1/22/16) and termination (195 DAP). This data was collected to assess cultivar tolerance of local insects and diseases. No significant differences in pest resistance were seen between lentil cultivars (Table 3). There was very little damage from disease or insects at 101 DAP on any cultivar. At termination, some minor damage from pests had occurred on all cultivars consisting of some leaf damage in the form of brown speckling and a few holes. These results indicate that these cultivars may show some tolerance to insects and diseases in the Central Valley.

Aboveground biomass was collected from each plot on the termination date (195 DAP) in order to compare productivity and as an adaptability indicator to the local environmental conditions. This data was also used for relative comparison of drought tolerance, since 2015 was a dry year (total annual precipitation = 10.3 inches) compared to 2016 (total annual precipitation = 16.7 inches). Biomass was not significantly different across cultivars (Table 3). Biomass collected during the 2016 season was compared to the biomass collected by lentil cultivar from demonstration plots during the previous year in 2015 (Figure 2). 'Cedar' produced the highest amount of biomass during both years, indicating that it has a high adaptability to either wet, or dry conditions. Following 'Cedar' was 'Richlea' and 'Pennell', which also had similar performance during both years. 'Merrit' and 'Brewer' had higher biomass production in the dry year of 2015 than in 2016, implying that they might be better suited for more arid environments. 'Shasta' produced more biomass during 2016 than 2015, but was a low biomass producer overall.

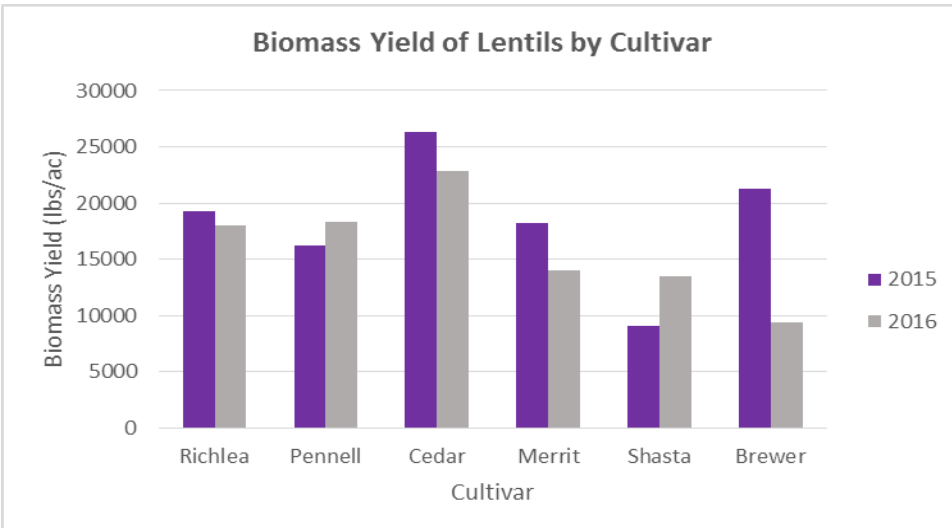

Figure 2. Mean biomass yield of lentil cultivars at the Lockeford PMC in 2015 and 2016.

Nitrogen content was collected from cultivar composite samples of dried aboveground biomass in order to evaluate the potential nitrogen accumulation and contribution to subsequent crops. Lentil cultivars with the largest biomass also had the highest total nitrogen yield (Table 4). 'Cedar' had the highest total nitrogen yield at almost 160 lbs/acre, indicating that it may contribute N to later crops and has the potential to reduce nitrogen fertilizer additions (Table 4). 'Brewer' had the lowest total nitrogen yield (about 30 lbs/acre), implying that it may not be the best cover crop choice for someone looking to reduce nitrogen inputs (Table 4).

Table 4. Total percent nitrogen in dry lentil biomass by cultivar in 2016 (composite samples).

Total % Nitrogen in Dry Lentil Biomass			
Cultivar	Total N Content (%)	Dry yield (g/sq ft)	Total % N (lbs/ac)
Brewer	2.57	12.11	29.88
Cedar	2.26	73.54	159.60
Merrit	2.31	44.29	98.26
Pennell	2.54	53.80	131.23
Richlea	2.47	52.12	123.64
Shasta	2.29	38.31	84.26

Canopy cover evaluations were collected twice during the growing season. One evaluation was collected at 101 DAP (1/22/16), while the second evaluation was collected at 195 DAP (termination). This evaluation was collected to provide an estimate of the percent of groundcover over time and to estimate the cultivars' ability to suppress weeds. A mean separation test was performed on the canopy cover data, in addition the AOV analysis, to determine which cultivars were significantly different from each other (Table 5). 'Richlea' and 'Brewer' had the highest percentage of canopy cover at 101 DAP. Their coverage was significantly higher than the coverage of 'Cedar' and 'Shasta' cultivars (Table 5, Figure 3). 'Pennell' and 'Merrit' also had canopy covers that were significantly higher than 'Shasta'. At 195 DAP, all canopy cover percentages were reduced due to extremely high weed pressure in the plots. Some significant differences were still seen between cultivars, including 'Richlea', which was significantly higher than 'Merrit', 'Brewer', and 'Shasta'. 'Richlea' was the only lentil cultivar able to provide significantly higher canopy coverage throughout the growing season, compared to the other cultivars. This indicates that 'Richlea' may be able to maintain some weed suppression ability, even in high pressure situations. On the other hand, 'Shasta' significantly had the lowest canopy cover throughout the growing season implying that it would not be good weed competitor.

Table 5. Canopy cover evaluations taken across six lentil cultivars in 2016at the Lockeford PMC.

Canopy Cover of Lentil Cultivars (2016)		
Cultivar	Canopy Cover 101 DAP (%)	Canopy Cover 195 DAP (%)
Brewer	66.50 a	19.0 b
Cedar	47.50 bc	28.25 ab
Merrit	61.75 ab	19.0 b
Pennell	57.0 ab	28.50 ab
Richlea	71.25 a	38.0 a
Shasta	38.0 c	21.55 b

Means within columns followed by the same letters are not significantly different from each other (P<0.05).

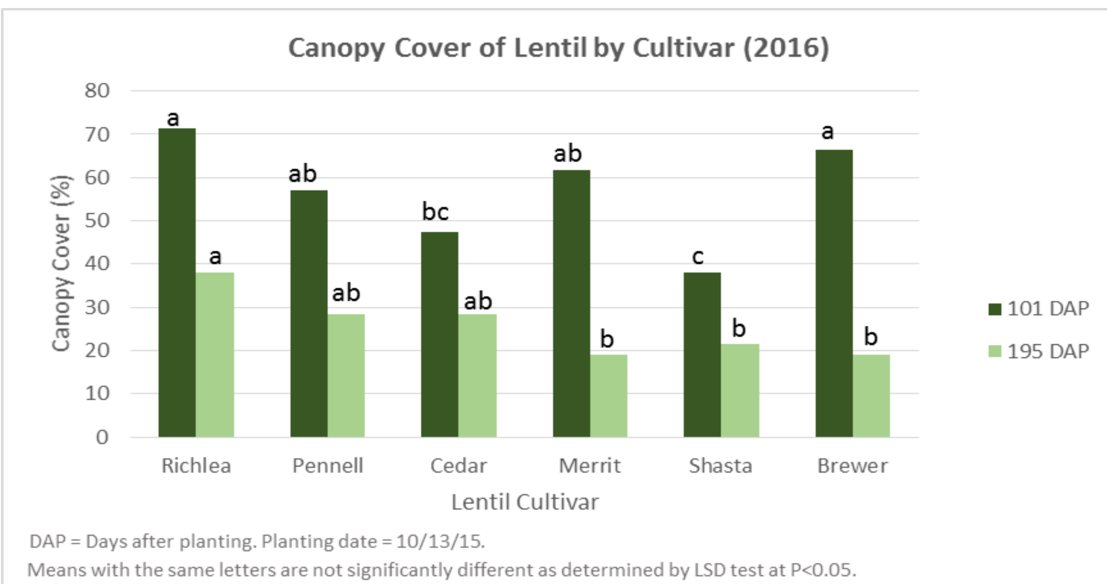

Figure 3. Lentil canopy cover by cultivar at 101 days after planting and 195 days after planting, which was also the termination date.

CONCLUSION

Lentils have the potential to work as a cover crop in California, especially in drought years and in semi-arid areas of the Central Valley. Due to their short stature, lentils would be a low frost risk in orchards and vineyards, which would reduce mowing requirements. Lentils also appear to be fairly resistant to disease and insect damage in this area of California's Central Valley.

General findings from this trial indicate that lentils are not able to outcompete or suppress weeds in high pressure situations. The use of lentils as a cover crop is not recommended in areas that have a history of high weed pressure. Some cultivars such as 'Richlea' and 'Brewer' were able to germinate and establish early, potentially suppressing early winter weeds. 'Richlea' may also be able to maintain some weed suppression throughout the season if there is moderate weed competition.

Biomass production and nitrogen contributions from lentil cover crops can help reduce additional nitrogen fertilizer costs, depending on climatic conditions and lentil cultivar. 'Cedar' had the highest contribution of total N yield, indicating that it has the potential as a green manure crop and may be able to supply nitrogen to subsequent crops. However, other cultivars, such as 'Brewer', had a much lower total nitrogen yield and would probably deplete soil nitrogen instead of replenish it.

Further evaluations need to be conducted at the CAPMC on several of these lentil cultivars for drought tolerance, water use, and optimum termination dates in California to maximize water storage and nitrogen fixation. This would help to ensure that lentils are a viable cover crop option in the Central Valley and that they are properly recommended for California agricultural operations.

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