TECHNICAL NOTES

U.S. Department of Agriculture **Natural Resources Conservation Service**

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Adaptation of Cover Crop Cultivars to California's Central Valley

Results of National Adaptation Trial 2016 – 2018

USDA NRCS Lockeford Plant Materials Center, CA

Daikon radish cultivar replicated plots 3/27/18.

Valerie Bullard, Agronomist, Lockeford Plant Materials Center, 21001 N. Elliott Rd., Lockeford, CA 95237, valerie.bullard@ca.usda.gov; 209-867-3101

INTRODUCTION

Incorporating cover crops into a cropping system improves soil health, conserves energy, builds resilience, and manages climate risk (Hargrove, 1986; Lal, 2004; Reeves, 1994; Reicosky and Forcella, 1998). Cover crops can be leguminous, or non-leguminous. Leguminous cover crop species provide a nitrogen source for subsequent commodity crops (Singh et al., 2004; Smith et al., 1987). Non-leguminous cover crops, such as small grains, are effective in reducing nitrate leaching and for soil erosion (Meisinger et al., 1991). Utilizing a mix of leguminous and non-leguminous cover crop species can provide multiple benefits. Selection of compatible species and cultivars that mature at the same time is important when developing diverse cover crop mixtures. While cover crops provide numerous agronomic and environmental benefits, these benefits are only achieved when cover crop varieties/cultivars are planted that meet the objective of the cover crop planting and the producer's expectations.

PURPOSE

This study evaluated growth characteristics and production attributes of commercially available varieties/cultivars and local sources of selected cover crops identified by NRCS State Agronomists, Soil Health Contacts, and Plant Materials Center staff. It was part of a national study to provide cover crop adaptation and growth data for different geographical regions in the U.S. The data collected will inform local recommendations for selection of adapted cover crops suitable for local areas and for use in mixtures, as well as future soil health studies.

MATERIALS AND METHODS

- Location: Plant Materials Center in Lockeford, California sits on a historical flood plain of the Mokelumne River, located on the eastern side of the San Joaquin Valley in central California.
- Experimental Design: Randomized Complete Block Design with 4 replications of 8 species and 59 cultivars. Plots were approximately 25 feet long by 5 feet wide with 9 rows at 7 inch spacing. Legumes were inoculated prior to planting.
- Cultivars: Austrian winter pea (8 cultivars), balansa clover (2), black oat (1) and black seeded oat (1), cereal rye (15), crimson clover (6), daikon radish (12), hairy vetch (6), and red clover (8) (Table 1).
- Evaluations: germination/field emergence, winter hardiness, beginning of regrowth, bloom and flowering period, plant height, disease and insect resistance, canopy cover, fresh weight aboveground biomass (FWAB), dry matter (DM) yield, and total nitrogen content (TN).
- 50% Bloom was used as a proxy for termination date as this is the time that nitrogen in above ground biomass is at maximum levels.
- Final determination of FWAB, DM and TN were taken at 50% bloom for all cultivars.

Table 1. Pure live seed (PLS) seeding rates of 59 cultivars planted at the Lockeford Plant Materials Center, CA 2016-2018.

Legume Species		
Common Name ***Species***	**Cultivar**	**Actual Seeding Rate (PLS lbs/ac)**
Austrian Winter Pea	Arvica 4010	74
Pisum sativum	Dunn	82
	Frost Master	82
	Lynx	82
	Maxum	77
	Survivor 15	74
	Whistler	78
	Windham	82
Balansa Clover	Fixation	23
Trifolium michelianum	Frontier	7
Crimson Clover	AU Robin	32
Trifolium incarnatum	AU Sunrise	43
	AU Sunup	20
	Contea	30
	Dixie	21
	Kentucky Pride	18
Hairy Vetch	CCS-Groff	20
Vicia villosa	Lana	18
	Purple Bounty	23
	Purple Prosperity	20
	TNT	24
	Villana	19
Red Clover	Cinammon Plus	15
Trifolium pratense	Cyclone II	15
	Dynamite	15
	Freedom!	15
	Kenland	11
	Mammoth	10
	Starfire	15
	Wildcat	15

Grass Species		
Common Name ***Species***	**Cultivar**	**Actual Seeding Rate (PLS lbs/ac)**
Black Seeded Oats	Cosaque	72
Avena sativa		
Black Oats - *Avena strigosa*	Soil Saver	61
Cereal Rye	Aroostook	111
Secale cereal	Bates	128
	Brasetto	112
	Elbon	114
	FL 401	111
	Guardian	112
	Hazlet	111
	Maton	112
	Maton II	110
	Merced	119
	Oklon	111
	Rymin	120
	Wheeler	105
	Wintergrazer 70	132
	Wrens abruzzi	119

Forb Species		
Common Name ***Species***	**Cultivar**	**Actual Seeding Rate (PLS lbs/ac)**
Daikon Radish	Big Dog	10
Raphanus sativus	Concorde	10
	Control	10
	Defender	10
	Driller	9
	Eco-till	9
	Graza	10
	Groundhog	11
	Lunch	10
	Nitro	9
	Sodbuster Blend	10
	Tilllage	10

RESULTS AND DISCUSSION

Grass Species

Cereal rye and oats have multiple benefits as cover crops. They grow rapidly in cool weather, produce large amounts of biomass, can be a good source of residue, provide weed suppression, and have quick growing fibrous roots that break up compaction, and hold the soil in place. They are also great cover crops for scavenging unused soil nitrogen, which is then trapped into their biomass, when it would otherwise be leached from the system. Bloom timing and biomass results from the cereal rye and oat species and cultivars are shown in Figures 1 and 4. The cereal rye cultivars were split up into two categories: winter cultivars and spring cultivars. Winter cereal rye cultivars require vernalization, or period of cold temperatures to initiate reproductive development, while spring cultivars do not require vernalization

50% Bloom

Bloom and flowering period were recorded for the grass species at 50% anthesis. This data provides termination timing information for the cover crop. Cereals should be terminated at or before 50% anthesis to prevent reseeding and allow maximum nitrogen accumulation to aid in residue decomposition. Merced and Florida 401 cereal rye were the first cereal species to reach maturity (50% anthesis) in late March (Figure 1). The other cereal rye cultivars flowered in mid-April (spring cereal rye) and late April/early May (winter cereal rye). Soil Saver (black oat) and Cosaque (black seeded oat) also reached maturity in late April/early May of both years.

Cereal Rye

Bates, Elbon, Maton, Maton II, Wintergrazer 70, and Wrens Abruzzi (spring cereal rye cultivars) were tall with high fresh weight aboveground biomass (FWAB) (Figure 4). Wheeler had the greatest height and FWAB of the winter rye cultivars (late Apr/early May flowering dates). Taller cultivars may not be desirable in all situations and may be more susceptible to lodging with high winds in spring. High residue cover crops can also be challenging to manage in annual cropping systems. Brasetto was last to flower, shortest in height, and had the lowest FWAB and dry matter (DM) yield production across both growing seasons. Florida 401 and Merced may be the first to flower (late March), but had lower FWAB and may be more susceptible to rust during a wet spring than other cereal rye cultivars.

Black Oats/Black Seeded Oats

Both Cosaque and Soil Saver had shorter height than the grass species median, but high FWAB (Figure 4). Soil Saver was shown to be more disease resistant and potentially more likely to shade out weeds than Cosaque, due to greater height and higher canopy cover at 50% anthesis. Concerns with management and frost in some California agricultural systems may point to Cosaque being a better fit, due to its shorter stature and higher biomass production.

Forb Species

Benefits of using daikon radish cover crops include rapid fall growth, large biomass production and weed suppression, and alleviating soil compaction due to a large taproot. They are also good cover crops for scavenging nutrients below the root zone of annual crops. Results from the daikon radish cultivars are shown in Figures 2, 5, and 6.

50% Bloom
Bloom and flowering period were recorded for the forb species at 50% bloom. This information is helpful for providing necessary windows for pollinator forage, as well as for estimated timing of termination of the cover crop. Big Dog, Driller, Eco-Till, Groundhog, Lunch, Nitro, Sodbuster Blend, and Tillage were the first cultivars to reach 50% bloom (mid-March), while Concorde, Control and Defender matured two weeks later (Figure 2). The last daikon radish cultivar to reach 50% bloom was Graza, which occurred in early/mid-April.

Daikon Radish
Biomass results show that radishes maturing in late March (Concorde, Control, and Defender) were tall with high FWAB (Figure 5). Cultivars that matured in mid-March with biomass above the FWAB median included Big Dog, Eco-Till, Groundhog, and Nitro daikon radish. Other mid-March maturing cultivars (including Driller, Lunch, Sodbuster Blend and Tillage) had short height and lower FWAB than the daikon radish median. The late maturing cultivar, Graza was tall with low FWAB and low canopy cover.

The total nitrogen content (TN) and DM yield results show Big Dog, Concorde, Control, Defender, Eco-Till, and Nitro with both high TN and DM yield, indicating good green manure potential (Figure 6). However, Defender and Eco-Till, would be the only two cultivars that may contribute nitrogen from aboveground biomass due to their C:N ratio, since their two-year average was above 3% (3.1% and 3.0%, respectively). Other cultivars may temporarily up nitrogen due to their lower TN content.

Legume Species

Legume cover crop species grow slowly in the fall in California, but root development will continue over the winter and growth will quicken in the spring. Legumes are able to fix nitrogen from the atmosphere and some are even able to smother spring weeds. The biomass and TN of these species can also substitute nitrogen fertilization needs. Results from the legume species and cultivars are shown in Figures 3, 7, and 8. There are two categories of winter pea, similar to cereal rye: winter cultivars and spring cultivars. Only winter pea cultivars were evaluated in this study.

50% Bloom
Bloom and flowering period were recorded for the legume species at 50% anthesis. This data provides flowering information for pollinators, indicates maximum nitrogen content in the aboveground biomass, and the termination date of the cover crop. Frontier balansa clover and AU Sunup crimson clover were some of the first legume species to reach maturity (50% bloom) in late March/early April, while other clovers bloomed later, in mid/late April (Figure 3). Arvica 4010, Dunn, and Maxium, were two of the first winter peas to bloom in mid-March in 2017 and mid-April in 2018, while Survivor 15 was last during both years, waiting until mid-May to reach maturity. Lana was the first hairy vetch to reach 50% bloom in late April/early May, while other hairy vetch cultivars bloomed in mid-May.

Balansa Clover
Both balansa clovers were short legumes, but Fixation had a higher FWAB than Frontier (Figure 7). Frontier had higher TN, but Fixation had higher DM yield, which translates to higher estimated total N yield (Figure 8). Fixation having higher contributions of biomass and estimated TN yield may be a better fit as a cover crop than Frontier. However, if early bloom is desired for pollinator forage, Frontier bloomed a month earlier than Fixation.

Austrian Winter Pea
Whistler was the only AWP cultivar that had FWAB above the legume median (Figure 7). All other pea cultivars had low FWAB. Dunn and Frost Master did not survive the 2018 growing season. Whistler also had high DM and estimated N yield above the legume median (Figure 8). Other cultivars had low DM yield and variable TN. These results indicate that different AWP cultivars may have different niche in California agricultural systems. Maxum would be a good option for an early blooming variety with high nitrogen content, Survivor 15 may be a good choice for a late blooming variety, and Lynx or Windham would be good choices if looking for mid-season bloom and high nitrogen, but low biomass. Whistler had the highest FWAB and DM yield across all cultivars and could be useful for its green manure and nitrogen contributions.

Crimson Clover
Nearly all crimson clover cultivars had high FWAB, except AU Sunup, which had FWAB below the legume median (Figure 7). Kentucky Pride was the tallest crimson clover cultivar evaluated. AU Sunup had the lowest crimson clover DM yield, and all crimson clover cultivars had TN below the legume median (Figure 8). AU Sunup was the first cultivar to reach 50% bloom, but it also produced the lowest amount of biomass. Dixie and Kentucky Pride bloomed later in the season and had high DM yield and relatively high TN content, indicating they could be useful as a green manure option.

Hairy Vetch
All hairy vetch cultivars had high FWAB and tall height (Figure 7). All cultivars were also high in DM yield and TN, leading to high estimated TN yield (Figure 8). Purple Prosperity fell just below the TN median. All hairy vetch cultivars performed similarly well in this study. Lana was the earliest to bloom, while Purple Prosperity, TNT, and Villana produced the highest FWAB, indicating these would be good choices for green manure. TNT also had the highest DM yield and TN making it a great option for adding nitrogen to a system.

Red Clover
Red clover cultivars did not start blooming until early/mid-June and did not reach full bloom until late-June/early July during both growing seasons. Due to the late bloom date, minimal results were collected from the red clover cultivars. Due to the late emergence and bloom dates in this trial, red clover may not be a good choice as a cool season cover crop in California. However, it may fit as a mixture component for permanent tree crops where late bloom is desirable, or as a warm season cover crop for pollinators and beneficial insects, as well as nitrogen fixation

CONCLUSION

Most of the cover crop species and cultivars evaluated in this trial performed well in the Central Valley of California. However, differences in maturity dates, growth and nitrogen content show that cultivar choice can make a big difference in agronomic benefits.

The successful cereal cover crops and cultivars included both the Soil Saver black oat and Cosaque black seeded oat cultivars, as well as Bates, Elbon, Maton, Maton II, Wintergrazer 70, Wrens Abruzzi, and Wheeler cereal rye cultivars. Brasetto cereal rye had the lowest FWAB and DM yield production. Big, Dog, Concorde, Control, Defender, Eco-Till, and Nitro daikon radish cultivars performed well. However, Graza daikon radish may not be the best cultivar choice for weed competition in the San Joaquin Valley, due to slower emergence. The Austrian winter pea cultivars that produced the most biomass and estimated total nitrogen yield over the two years were Maxum which blooms early (mid-March to mid-April) and Whistler, which blooms later (late April/early May). The clover cultivars that were well adapted to the central valley conditions included Fixation balansa clover, Dixie, and Kentucky Pride crimson clover cultivars. Frontier balansa clover and AU Sunup crimson clover could be useful for pollinator forage, due to their early bloom dates. All hairy vetch cultivars were well adapted to the area including Purple Prosperity, TNT, and Villana, with Lana being the earliest to flower. Red clover did not fit into the cool season cover crop time frame for this area, but would have a better fit as a spring cover crop.

Next steps include developing U.S. regional recommendations for cover crop cultivars and mixes based on these results. Effective cover crop cultivars will need further evaluation in other regions within California and implemented into specific farming operations to estimate their compatibility and success with different agricultural systems and practices.

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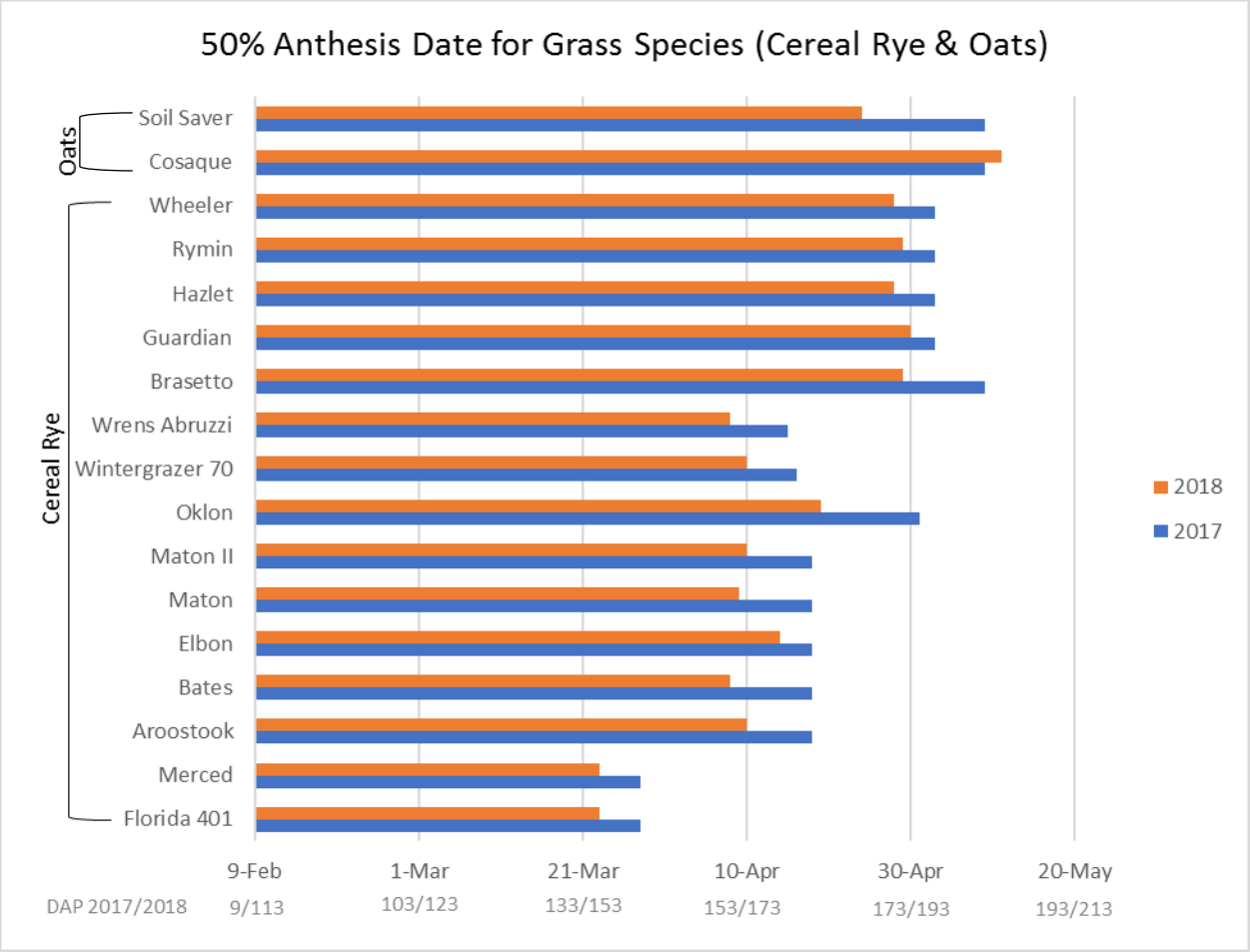

Figure 1. Differences between 50% anthesis dates of grass species and cultivars across two growing seasons. DAP = Days after planting; Planting dates for 2017 were 2 weeks earlier than in 2016.

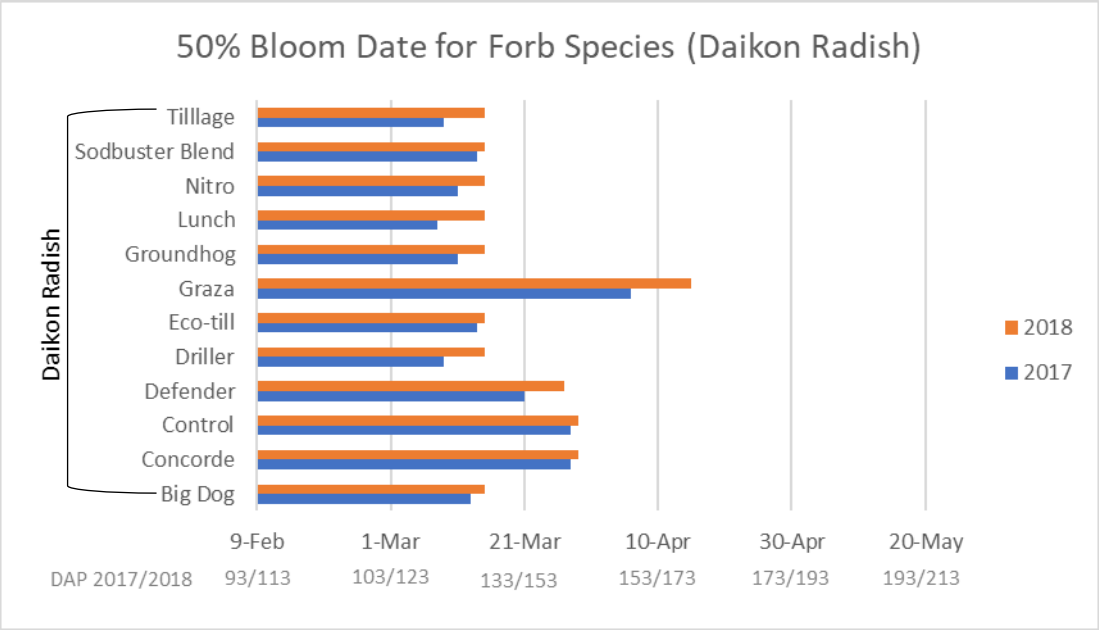

Figure 2. Differences between 50% bloom dates of daikon radish cultivars across two growing seasons. DAP = Days after planting; Planting dates for 2017 were 2 weeks earlier than in 2016.

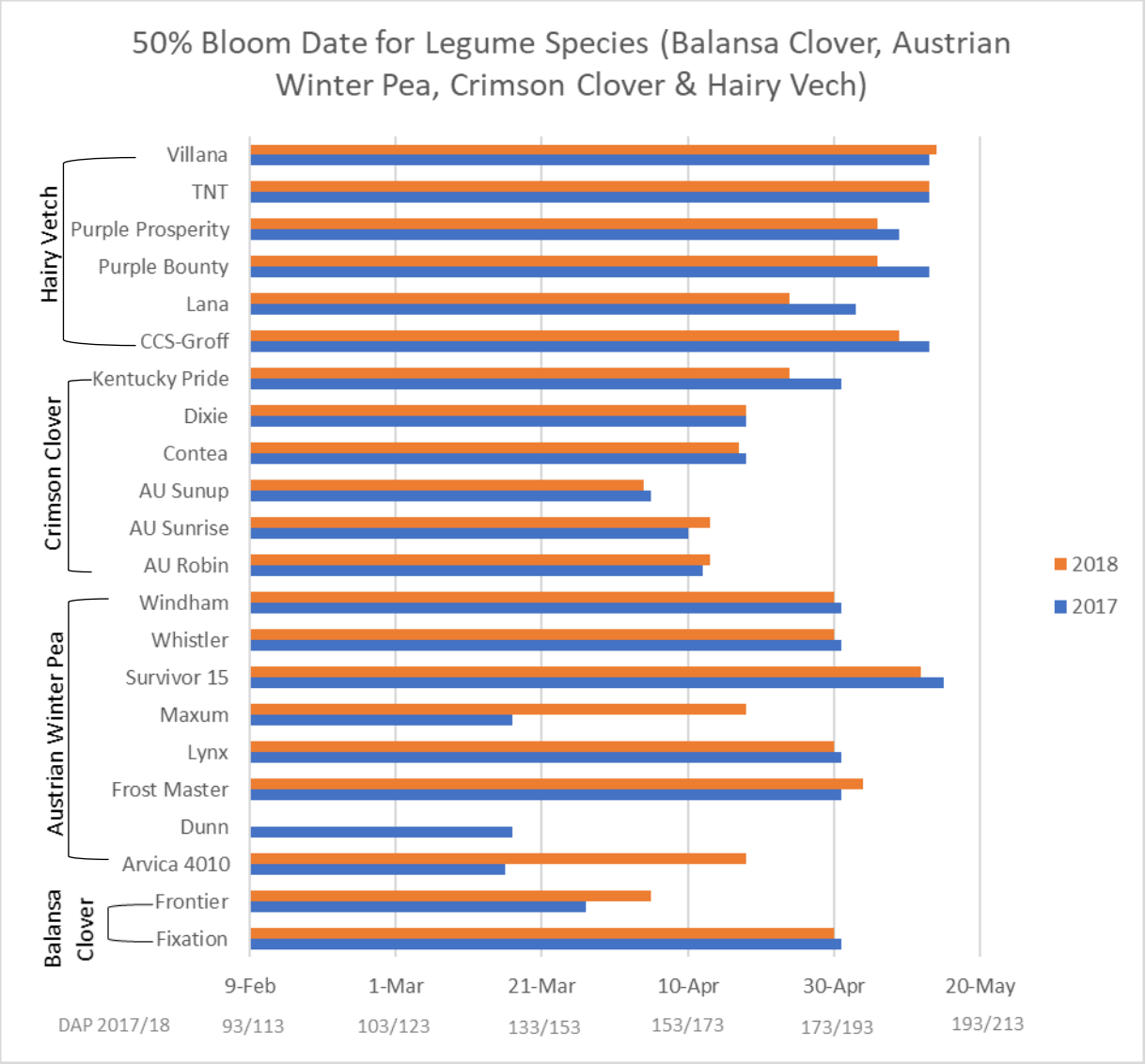

Figure 3. Differences between of 50% bloom dates legume species and cultivars across two growing seasons. DAP = Days after planting; Planting dates for 2017 were 2 weeks earlier than in 2016.

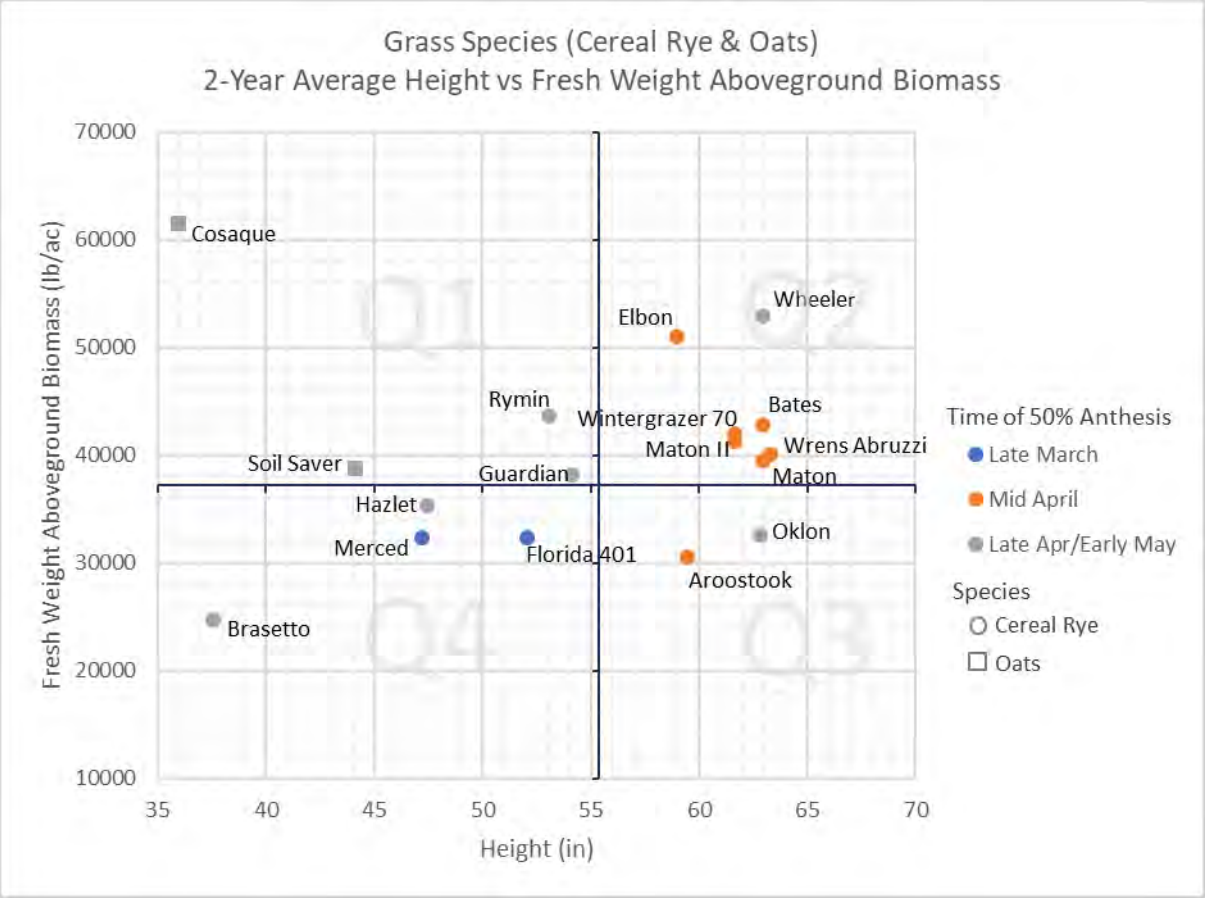

Figure 4. Differences shown between grass species and cultivars across a two-year average of height versus FWAB at 50% anthesis. Axes represent the median of grass height data (55.4 inches) and grass FWAB data over two years (37,229 lb/ac) and break the graph into four quadrants. In the resulting quadrants Q1 = shorter height with high biomass, Q2 = tall with high biomass, Q3 = tall with low biomass, and Q4 = short with low biomass. The cultivars with the earliest maturity fell into Q4 with both short height and low FWAB. Most of the cereal rye cultivars maturing in mid-April (spring cereal rye) fell in Q2 with both tall height and high FWAB compared to the other grass species. The later maturing cereal rye (winter cereal rye) were variable, falling in all four quadrants. The oat species fell into Q1 with shorter height than the grass species median, but high FWAB. This represents only two years of data and over the course of time the cultivar will settle into the quadrant that most likely reflects their performance.

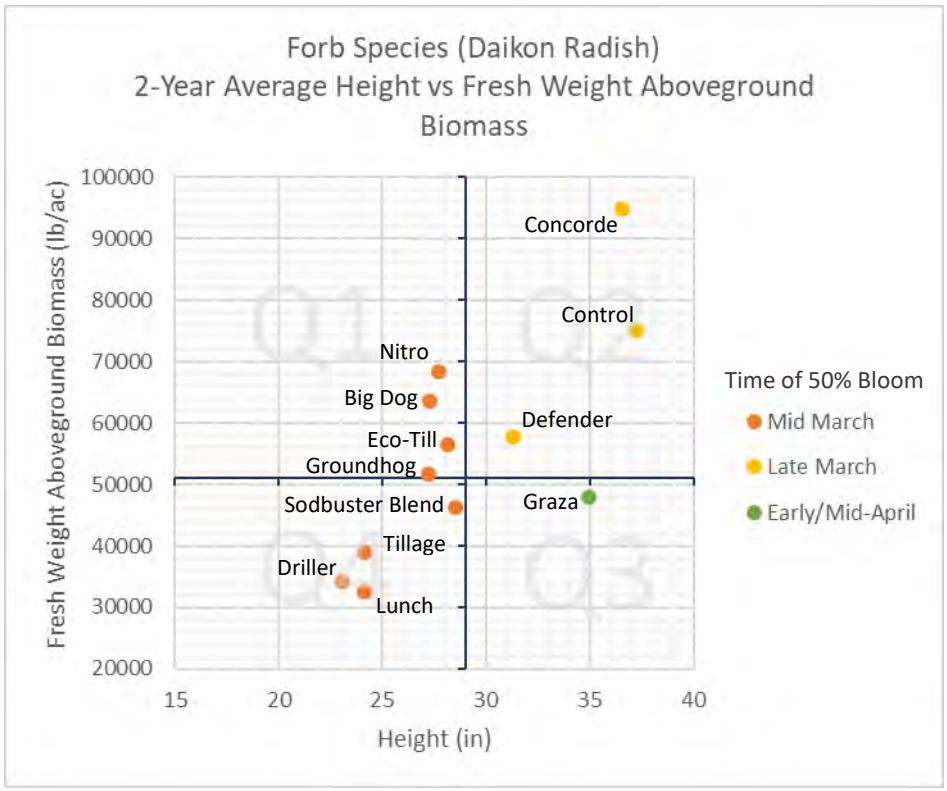

Figure 5. Differences shown between daikon radish cultivars across a two-year average of height versus FWAB at 50% bloom. Axes represent the median of daikon radish height data (29 inches) and daikon radish FWAB data (51,018 lb/ac) and break the graph into four quadrants. In the resulting quadrants Q1 = shorter height with high biomass, Q2 = tall with high biomass, Q3 = tall with low biomass, and Q4 = short with low biomass. Radishes maturing in late March (Concorde, Control, and Defender) were grouped in Q2, being both tall and with high FWAB. Other cultivars that matured in mid-March with average biomass above the FWAB median included Big Dog, Eco-Till, Nitro, and Groundhog daikon radish. The late maturing cultivar, Graza, is shown in Q3 with low FWAB, but tall height.

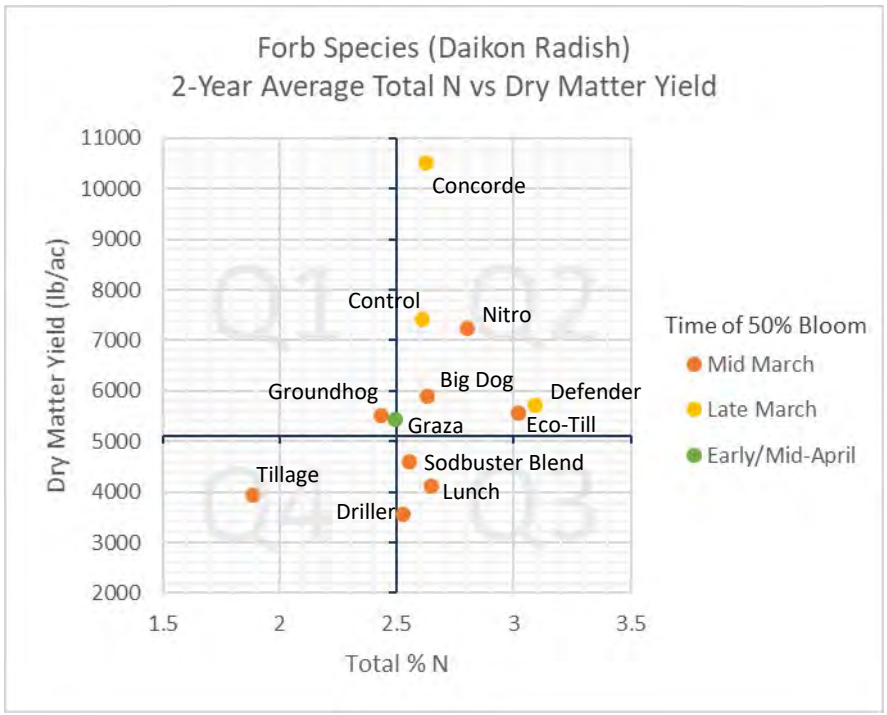

Figure 6. Differences shown in estimated nitrogen (N) yield between daikon radish cultivars across a two-year average of total N content versus dry matter (DM) yield at 50% bloom. Axes represent the median of daikon radish total N data (2.5 %) and daikon radish DM yield data (5,108 lb/ac) and break the graph into four quadrants. In the resulting quadrants Q1 = high DM, but low N, Q2 = high DM and high N translating to high estimated total N yield, Q3 = low DM, but high N, and Q4 = both low DM and low total N. Big Dog, Concorde, Control, Defender, Eco-Till, and Nitro had both high total N content and DM yield, located on Q2. However, Defender and Eco-Till, would be the only two cultivars that may contribute nitrogen, since their two-year average was above 3%. Other cultivars may temporarily tie up nitrogen due to their lower nitrogen content.

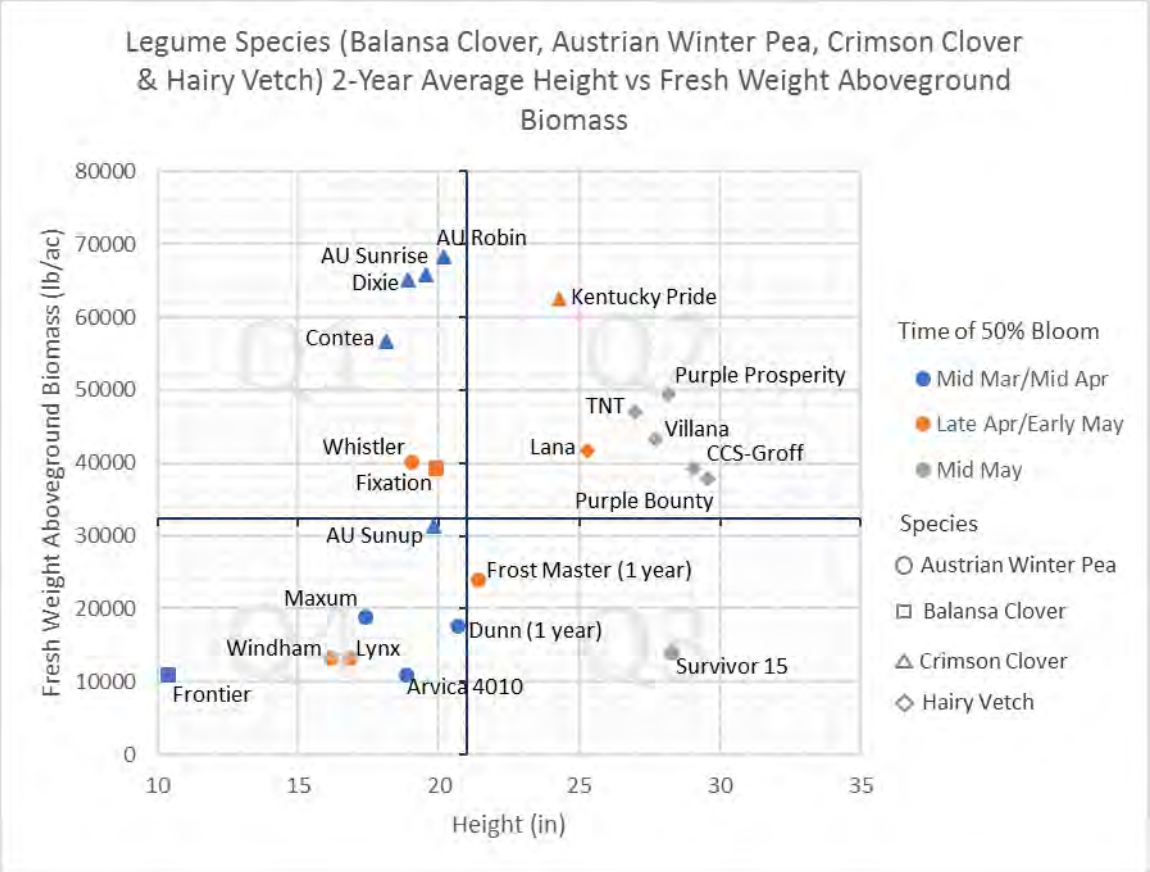

Figure 7. Differences shown between legume species and cultivars across a two-year average of height versus FWAB at 50% bloom. Axes represent the median of legume height data (21 inches) and legume FWAB data (32,411 lb/ac) and break the graph into four quadrants. In the resulting quadrants Q1 = shorter height with high biomass, Q2 = tall with high biomass, Q3 = tall with low biomass, and Q4 = short with low biomass. The majority of the crimson clover cultivars fell in Q1 with high FWAB and median height; all hairy vetch cultivars fell into Q2 with both tall height and high FWAB; the Austrian winter peas fell in Q3 and Q4 with variable height and low FWAB (except for Whistler); the balansa clover cultivars varied widely across quadrants.

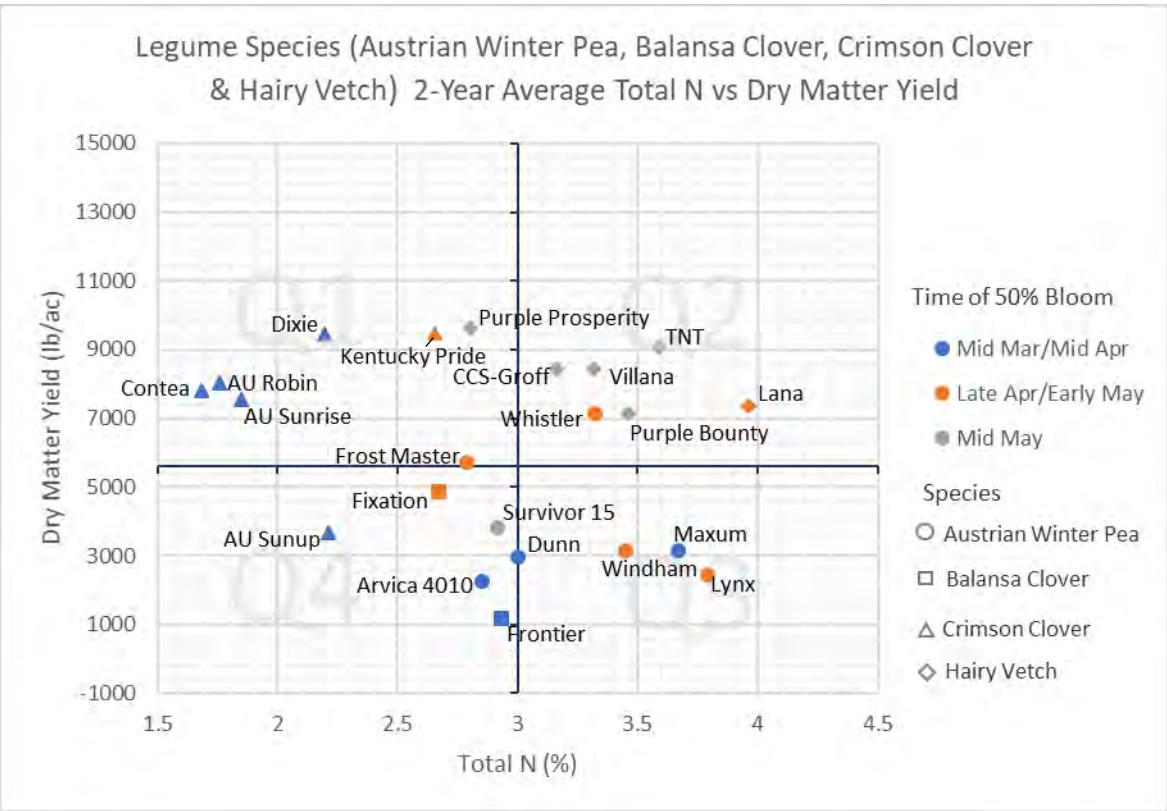

Figure 8. Differences shown in estimated nitrogen (N) yield between legume species and cultivars across a two-year average of total N content versus dry matter (DM) yield at 50% bloom. Axes represent the median of legume total N data (3.0 %) and legume DM yield data (5522 lb/ac) and break the graph into four quadrants. In the resulting quadrants Q1 = high DM, but low N, Q2 = high DM and high N translating to high estimated total N yield, Q3 = low DM, but high N, and Q4 = both low DM and low total N. All the crimson clover cultivars (except AU Sunup) are located in Q1, with high DM, but lower total N than other legume species. All the hairy vetch cultivars (except Purple Prosperity) fell in Q2 with both high DM yield and total N. Most of the Austrian winter pea cultivars fell in Q3 and Q4 with lower DM yield than the median and variable N. Whistler was the only winter pea with high DM and estimated N yield. The balansa clover cultivars fell into Q4 with lower DM yield and N, than the legume medians.


a)

b)

Figure 9. a) Hairy vetch biomass sampling on 5/10/18. b) Crimson clover biomass sampling in 4/11/18.