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# Cover Crop Variety Adaptation Trial 2016 - 2018

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## ABSTRACT

*Cover crops are increasingly used in agriculture and provide numerous benefits including improved soil health, enhanced nutrient cycling and retention, increased water holding capacity, and competitive suppression of weeds. Other benefits may include lower use requirements for fertilizer and herbicide, and greater drought tolerance. There are numerous cover crop choices available on the market, but little is known about the adaptability of certain cultivars and varieties to specific regions in the United States. In this national trial, eight species and 59 different cover crop cultivars were evaluated for adaptation to the California Central Valley at the Lockeford Plant Materials Center. Evaluations included germination/field emergence, winter hardiness, beginning of regrowth, bloom and flowering period, plant height, disease and insect resistance, canopy cover, aboveground biomass, and total nitrogen content. This report includes two years of evaluation data and observations at the Lockeford trial location. Performance was assessed, and most of the cover crop species and cultivars evaluated in this trial performed well in the Central Valley of California. Trends were seen in both growth characteristics and production in terms of bloom time, nitrogen content, and biomass production between cultivars, indicating that cultivar choice can make a big difference in the agronomic benefits of a cover crop. Effective cover crop cultivars will need further evaluation in the diverse agricultural systems and environments of California to determine their compatibility and success with specific farming management operations.*

## 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 preventing soil erosion and reducing nitrate leaching (Meisinger et al., 1991). Utilizing a mix of leguminous and non-leguminous cover crop species can provide numerous agronomic and environmental benefits. The value of cover crops is not fully achieved unless cover crop varieties/cultivars are planted that meet the objective of the planting and producer's expectation.

The purpose of this nationwide trial is to evaluate 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 is part of a national study to provide cover crop adaptation and growth data for different

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geographical regions in the U.S., and inform local recommendations for cover crops as well as future soil health studies.

In 2012, the crop-land area estimated to be planted into cover crops was only 5% nationwide, in row cropping systems (Dunn et al. 2016). A significant limitation to the adoption of cover crops in California is the concern for delayed planting of high-value cash crops and perceived competition between crops and cover crops for water and nutrients. When cover crops are grown, typically there is a need for early termination in February or March, due to the climate and needs of the subsequent crop. The recent drought from 2012 – 2016 exacerbated the problem; with many producers reluctant to apply water to cover crops, and the concern for indirect competition for soil moisture. Fear of frost injury during early bloom and bud break is another major concern for orchards and vineyards. The huge diversity of cropping systems and microclimates within California will require developing cover cropping methods for each cropping system. Two areas where significant of research in cover crop systems is ongoing, are the arid irrigated southern Central Valley, with tomato and cotton (Mitchell et al. 2017) and organic vegetable production in the Salinas Valley on the Central Coast (Brennen et al. 2012 and 2013). Cool season cover crops in both these areas increase soil organic matter and infiltration of precipitation, but further long-term research is required to optimize the systems.

## MATERIALS AND METHODS

The adaptation trial was conducted during two years at the Plant Materials Center in Lockeford, California (CAPMC). 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 Mokelumne River. The soil series are Columbia and Vina fine sandy loams on 0-2 percent slopes. They are both very deep, well-drained soils with pH ranging from moderately acid to slightly alkaline. The mean annual maximum temperature in this area is 73.6°F and minimum temperature is 46°F (WRCC, 2018). The mean annual precipitation is 17.24 inches, mainly occurring between the months of December and March (WRCC, 2018). Precipitation totals were record breaking throughout California during the 2016-2017 growing season. Total precipitation between September 1, 2016 and August 1, 2017 at the Lockeford PMC was 32.05 inches, while precipitation was 16.80 inches between September 1, 2017 and August 1, 2018, shown in Figure 1 (WWG, 2018).

The trial was drilled on 11/8/16 and 10/19/17 with a Great Plains Cone Seeder. During the previous years, the two trial field locations were planted with cover crops. Mechanical and chemical methods were used over the summer and early fall to control weeds. The area was disked and cultipacked prior to planting. The trial was a randomized complete block design with four replications running from north to south. Plots were approximately 25 feet long by 5 feet wide with 9 rows at 7 inch spacing. Legumes were inoculated prior to planting.

A total of 59 different varieties/cultivars were provided by the Plant Materials Program with the assistance of seed vendors and individual PMC’s across the country. The species included Austrian winter pea (8 cultivars), balansa clover (2), black oat (1), black seeded oat (1), cereal rye (15), crimson clover (6), daikon radish (12), hairy vetch (6), and red clover (8) (Table 1). Target seeding rates of pounds per acre were standardized across species in the protocol. Actual seeding rates were adjusted based on Pure Live Seed (PLS) calculated from the germination and purity of the seed lot.

Weed pressure in the plots was especially high in the 2016/2017 growing season due to substantial precipitation after three years of drought in California. Weeds that were present in the plots during both years included shepherd's-purse (*Capsella bursa-pastoris*), little mallow (*Malva parviflora*), prickly lettuce (*Lactuca serriola*), ripgut brome (*Bromus diandrus*), fiddleneck (*Amsinckia intermedia*), annual ryegrass (*Festuca perennis*), burr medic (*Medicago polymorpha*), mustard (*Brassica nigra*), knotweed (*Polygonum arenastrum*), henbit (*Lamium amplexicaule*), common groundsel (*Senecio vulgaris*) and sowthistle (*Sonchus spp.*). There were also volunteers from other species plots including oats, vetch, and radish. Plots were hand hoed and sprayed with selective herbicide several times throughout the growing season to reduce weed competition for light and nutrients. The red clover plots were mowed at 6 inches twice during the year to reduce weed competition.

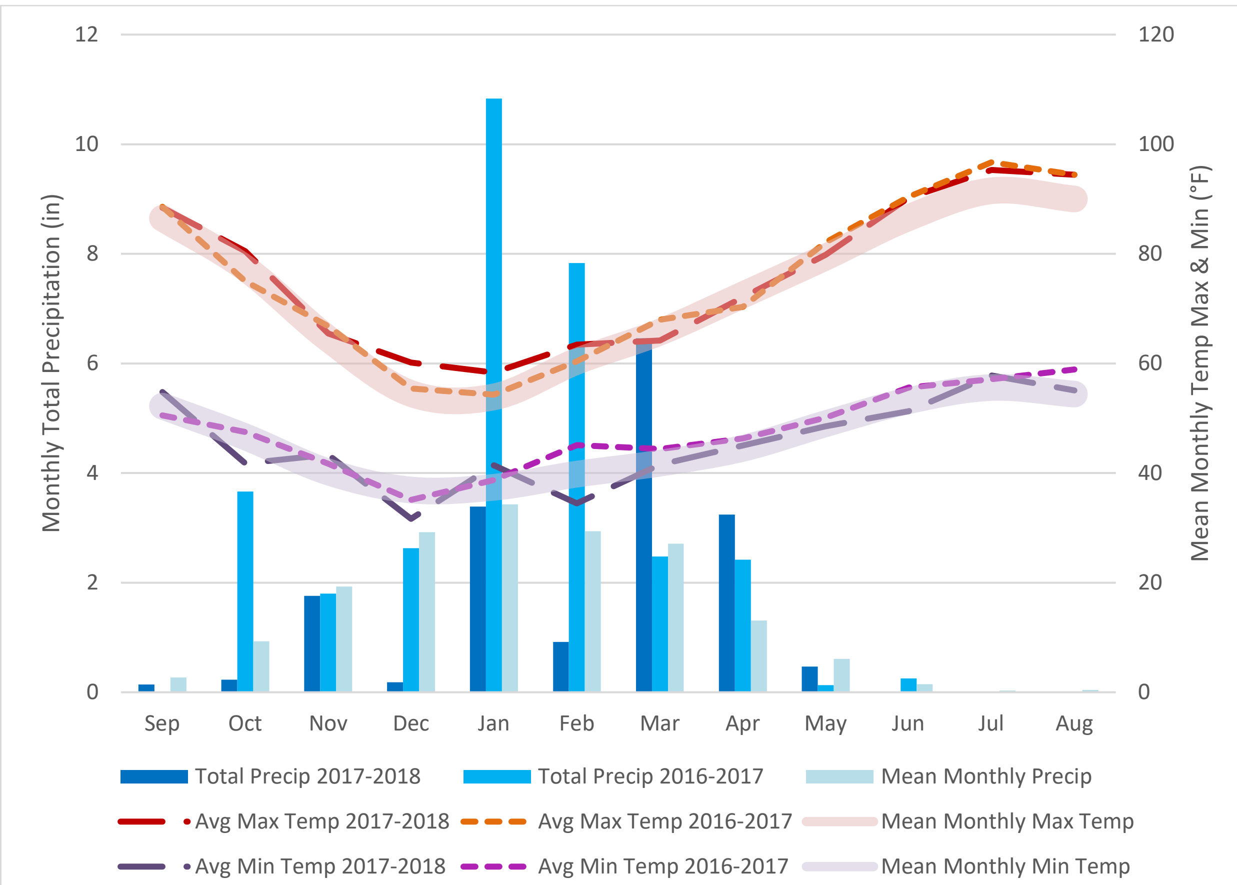


**Figure 1.** Mean minimum and maximum temperatures in the 2016/2017 and 2017/2018 growing seasons generally followed annual averages. Total precipitation was nearly double the annual average in 2016/2017. Monthly weather data from September through August was provided from Western Weather Group Lockeford Weather Station located directly across the river from the CAPMC. Average weather summaries from 1893-2015 for the Lodi area were provided from Western Regional Climate Center.

Several evaluations were collected during the 2016/2017 and 2017/2018 growing seasons following the national cover crop adaptation trial protocol, including: germination/field emergence, winter hardiness, beginning of regrowth, bloom and flowering period, plant height, and disease and insect resistance. Additional evaluations collected by the CAPMC included canopy cover, fresh weight aboveground biomass (FWAB), and total nitrogen (TN) content.

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

**Legume Sp.**

| 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 Sp.**

| 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 Sp.**

| 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 |

Germination/field emergence was defined as how well the species germinated and emerged after planting. Germination/emergence was visually evaluated 7, 14, 21 and 28 days after planting (DAP) 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). Winter hardiness was the percentage of the seedlings that emerged in the fall and survived over the winter. Live seedlings from the seeded cover crop were counted along a three-foot length of row at 28 days after planting. Seeded cover crop plants that survived over the winter were recounted along the same three-foot section of row in each plot following winter dormancy and the beginning of regrowth. Beginning of regrowth was when plants began active growth in the spring following winter dormancy. Active regrowth in the spring was observed and recorded in cover crops through the initiation of new leaves and tillers. Bloom and flowering period were recorded from the start of first bloom to 50% bloom or 50% anthesis. This data provides flowering information for pollinators, indicates optimum nitrogen content in the aboveground biomass, and was the termination date of the cover crop. Plant height was defined as the average height of lush canopy growth at 50% bloom/anthesis. Plant height was collected in inches from three random locations within each plot from the base of the plant to the top of the inflorescence. Disease and insect resistance was a visual estimate of the resistance to foliar diseases and insect damage. Plots were rated at beginning of regrowth and at 50% bloom/anthesis on a 0 - 5 scale, where 0 = no damage and 5 = severe damage.

Canopy cover was a visual estimate of the percentage of ground covered by the seeded species. Plots were evaluated 30, 60, 90, 120, 150, and 180 days after planting and at 50% bloom/anthesis. Evaluations were based on a 1 - 5 scale where 1 = 1% - 20% canopy cover, 2 = 21% - 40%, 3 = 41% - 60%, 4 = 61% - 80%, and 5 = 81% - 100% canopy cover. Results were then multiplied by 19 to transpose the rating to a percentage. Fresh weight aboveground biomass (FWAB) was defined as the aboveground accumulation of plant growth taken at ground level at 50% bloom/anthesis. A square foot area was harvested leaving no more than ¼ inch stubble height from a representative area within each plot and then weighed. Composite FWAB samples were dried and weighed to get a dry matter (DM) determination for percent DM yield and sent to a lab for percent total nitrogen (TN) analysis. TN content was defined as the nitrogen concentration in the aboveground portion of the biomass and expressed as a percent. TN yield (lb/ac) was calculated using the percent DM yield and percent TN content (both not replicated).

Statistical analysis was run on the evaluations collected from the 2016/2017 and 2017/2018 trial using Statistix 10 (Analytical Software, Tallahassee, FL). Ordinal data was analyzed using Kruskal-Wallis one-way analysis of variance (AOV) and Dunn's All-Pairwise Comparisons Test to separate means at the 5% level. Analysis was done on quantitative plant measurements using the analysis of variance (AOV) procedure for a randomized complete block design (RCBD) along with Tukey’s 1 Degree of Freedom test for non-additivity. Significant means were separated with Tukey’s Honestly Significant Difference (HSD) All-Pairwise Comparisons Test at the 5% level.

## RESULTS AND DISCUSSION

### *Austrian Winter Pea*

Results from the Austrian winter pea (AWP) cultivars varied widely over the two year study due to dramatic differences in precipitation patterns. Quantitative and ordinal data results from both seasons are shown in Tables 2, 3, and 4. Bloom dates are shown in Figure 2. Height versus FWAB, and TN versus DM yield are shown in Figures 3 and 4. Axes in Figures 3 and 4 represent the median of the Austrian winter pea cultivar data across two years and break the graphs into four quadrants.

The first AWP cultivars to reach 50% bloom were Arvica 4010 and Maxum, during both the 2017 (mid-March) and 2018 (mid-April) growing seasons (Table 2 and Figure 2). The last cultivar to reach 50% bloom was Survivor 15, during both years (mid-May). A significant difference in height was shown between AWP cultivars during the first growing season (2016/2017). Survivor 15 (30.8 inches) was significantly taller than Dunn (20.7 inches), Lynx (17.5 inches), Maxum (20.3 inches), Whistler (21 inches), and Windham (18 inches) using Tukey's HSD at the 5% level (Table 2). No significant differences were seen in height during the second season, or in winter hardiness counts and FWAB during either year. However, trends were seen between FWAB, DM yield and nitrogen content (Figures 3 and 4). Maxum and Whistler had average values of FWAB (18,902 lb/ac and 40,102 lb/ac, respectively), DM yield (3,172 lb/ac and 7,135 lb/ac) and TN (3.7% and 3.3%) at or above the AWP median values (FWAB: 16,633 lb/ac; DM yield: 3,192 lb/ac; TN: 3.3%) indicating that these cultivars may be a good choices for green manure and nitrogen contribution.

In the ordinal data, there were significant differences in ranks between cultivar gemination according to Kruskal-Wallis one-way analysis of variance, but no separation of the ranks was achieved with Dunn's all pairwise comparison test. Numerically, Arvica 4010, Dunn, Maxum, and Survivor 15 had higher germination at 28 DAP than the other AWP cultivars, with 65-85% in 2017 and 90-100% in 2018. Insect damage at 50% bloom, in the form of a few holes in leaves, was slight to moderate during both years with no significant differences. Disease resistance at 50% bloom showed significant differences during the second season due to high disease pressure from heavy spring rain, causing entire plants to turn brown and wilt. Dunn did not survive long enough to reach bloom, while Arvica 4010 and Maxum had significantly more disease damage (severe) than Lynx and Whistler (slight-moderate) using the Kruskal-Wallis one-way AOV and Dunn's All-Pairwise Comparisons Tests at the 5% level (Table 4). Differences were also seen between cultivars in canopy cover at 50% bloom with Whistler having significantly higher (76%) canopy cover compared to Arvica 4010 and Maxum (19% and 24%, respectively) during the second growing season. This was likely a reflection of the severe disease damage shown by both cultivars during the 2018 growing season.

This data suggests that different Austrian winter pea cultivars may be appropriate for specific situations in California. 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 pea varieties and could therefore contribute a considerable amount of green manure and plant available nitrogen to a system. Also, it is better to grow peas as a component in a mix rather than a solid stand, to help buffer potential disease issues in the event of a wet spring.

***Balansa Clover***

Two growing seasons of quantitative and ordinal data results for balansa clover cultivars are shown in Tables 5, 6 and 7. Bloom dates are shown in Figure 5, while height versus FWAB, and

TN versus DM yield are shown in Figures 6 and 7. Axes in Figures 6 and 7 represent the median balansa clover cultivar data across two years and break the graphs into four quadrants.

Frontier bloomed earlier (late March to early April) in the season than Fixation (late April) during both years (Table 5 and Figure 5). A significant difference in height was shown between cultivars in the 2016/17 growing season using Tukey's HSD at the 5% level with Fixation growing twice as tall (21 inches) as Frontier (10.5 inches) (Table 5). No significant differences were seen in height during the second season. No significant differences were seen in winter hardiness counts, or FWAB during either year. However, Fixation's two-year average values of FWAB (39,183 lb/ac) and DM yield (4,832 lb/ac) were higher than the balansa clover median values (FWAB: 14,574 lb/ac; DM yield: 1,754 lb/ac) (Figures 6 and 7). Frontier's two-year TN averaeg fell right on the median line at 2.9%, while Fixation was 2.7%. In the end, Fixation had a higher estimated TN yield due to the higher DM production (Table 6).

In the ordinal data, significant differences were seen in germination during the 2016/17 growing season at 14, 21, and 28 DAP using the Kruskal-Wallis one-way AOV and Dunn's All-Pairwise Comparisons Tests at the 5% level, with Fixation emerging significantly faster (65-85% at 14 DAP) than Frontier (<30% at 28 DAP) (Table 7). No differences were seen during the second season due to lack of germination at 28 DAP. Frontier was significantly more resistant to insect injury showing only slight damage compared to Fixation which had slightly-moderate damage. Damage was evaluated as only a few holes in the leaves during both growing seasons. No significant differences were seen in germination at 7 DAP, disease resistance, insect resistance at the time of regrowth, or percent canopy cover during either growing season.

Fixation balansa clover appears to be a better choice for a fast emerging and taller cultivar. It also had higher contributions of biomass and estimated nitrogen yield when compared to Frontier. However, if early bloom is desired for pollinator forage, Frontier bloomed a month earlier and had significantly less insect damage than Fixation.

***Black Oat/Black Seeded Oat***

Results from the black oat (Soil Saver) and black seeded oat (Cosaque) cultivars across the two growing seasons are shown in Tables 8, 9, and 10. Bloom dates are shown in Figure 8, while height versus FWAB are shown in Figure 9. Axes in Figure 9 represent the median of black oat and black seeded oat cultivar data across two years and break the graphs into four quadrants.

Soil Saver reached 50% anthesis in early May during the 2016/17 growing season and late April during the 2017/18 growing season. Cosaque reached 50% bloom in early to mid-May during both years. A significant difference in height was shown between cultivars during both the 2017 and 2018 growing season with Soil Saver being significantly taller (53.5 inches and 34.8 inches) than Cosaque (41 inches and 31 inches) using Tukey's HSD at the 5% level (Table 8). No significant differences were seen in winter hardiness counts, or FWAB. In the two-year average, Cosaque produced more FWAB and DM yield (61,480 lb/ac and 15,195 lb/ac, respectively) then Soil Saver (38,737 lb/ac and 10,318 lb/ac) (Table 9 and Figure 9). Due to their low TN content (<1.5%), both cultivars (like most cereals) would tie up instead of contribute nitrogen.

In the ordinal results for the 2016/17 growing season, significant differences were shown in disease resistance and canopy cover at 50% anthesis using the Kruskal-Wallis one-way AOV and

Dunn's All-Pairwise Comparisons Tests at the 5% level (Table 10). Soil Saver (slight damage) was significantly more resistant to disease than Cosaque (moderate damage), which showed signs of rust during the 2016/17 growing season. Soil Saver also provided more canopy cover at 50% anthesis (90.3%), than Cosaque (76%) during the first year. No significant differences were seen in disease resistance or canopy cover at 50% anthesis during the second season. No significant differences were seen in germination, insect resistance, disease resistance at the time of regrowth during either year.

Soil Saver has the potential to shade out weeds quickly, due to its tall height and high canopy cover at 50% anthesis, while Cosaque would be a good choice for high biomass production and DM yield. Concerns with frost in some California agricultural systems may also lead to Cosaque being a better fit due to its shorter stature.

***Cereal Rye***

Results from the cereal rye cultivars for the two growing seasons are shown in Tables 11, 12 and 13. Anthesis dates are shown in Figure 10, while height versus FWAB is shown in Figure 11. Axes in Figure 11 represent the median of cereal rye cultivar data across two years and break the graphs into four quadrants. 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.

*Spring Cereal Rye*

The earliest spring cereal rye cultivars to reach 50% anthesis were Florida 401 and Merced, which were in late March. The other spring rye cultivars reached 50% anthesis during mid-April (Figure 10). There were no significant differences in height, winter hardiness, or FWAB in the spring rye cultivars (Table 11). However, trends between height and FWAB across the two-year averages show that Bates, Elbon, Maton, Maton II, Wintergrazer 70, and Wrens Abruzzi were all tall and had high FWAB that were above the cereal rye median values (height: 56.6 inches; FWAB: 37,229 lb/ac) (Figure 11). Elbon had the highest two-year average FWAB of the spring rye cultivars (51,034 lb/ac).

In the first year (2016/17) of ordinal data, there were no differences in germination, insect resistance, or canopy cover at 50% anthesis across the spring rye cultivars (Table 13). There were significant differences in ranks between disease resistance of spring rye cultivars according to Kruskal-Wallis one-way analysis of variance, but no separation of the ranks was achieved with Dunn's all pairwise comparison test. Generally, all the cultivars germinated within 14 DAP and had only slight to moderate disease damage, and little to no insect damage. At 50% anthesis the canopy cover was 80-95% during both years. During the second year (2017/18) there were significant differences in germination at 7 DAP, as well as disease resistance at 50% anthesis using the Kruskal-Wallis one-way AOV and Dunn's All-Pairwise Comparisons Tests at the 5% level (Table 13). Aroostook was the first spring rye to reach 90-100% germination at 7 DAP, significantly earlier than Maton II (30-60%) during a dry October. Florida and Merced rye had significantly higher disease damage from rust (moderately-severe) than Maton (slight) at 50% anthesis.

Bates, Maton, Maton II, Wintergrazer 70, and Wrens Abruzzi were all tall cultivars with high FWAB. Elbon had the largest two-year average production of FWAB and DM yield of the spring rye cultivars. Florida 401 and Merced were the first to flower, had low FWAB, and may be more susceptible to rust during a wet spring than other spring cereal rye cultivars.

*Winter Cereal Rye*

The earliest winter cereal rye to reach 50% anthesis was Oklon in mid to late April. The other winter rye cultivars reached 50% anthesis in late April/early May (Figure 10). Using Tukey's HSD at the 5% level, Oklon (61 inches (2016/17); 64.7 inches (2017/18) and Wheeler (63 inches; 62.9 inches) were significantly taller than Hazlet (50.8 inches; 44.1 inches) during both years and significantly taller than Guardian (49.8 inches) and Rymin (50.4 inches) during the 2017/18 growing season (Table 11). Brasetto was significantly shorter (40.8 inches; 34.4 inches) than all other winter cultivars during both years. During 2016/17 growing season Guardian (54,019 lb/ac), Rymin (57,620 lb/ac), and Wheeler (67,224 lb/ac) had significantly higher FWAB than Brasetto (22,808 lb/ac). No significant differences were seen in FWAB in 2017/18 season between winter rye cultivars. Trends across the two-year averages also show that Wheeler had both the tallest height and highest FWAB of the winter rye cultivars, above the cereal rye median values (height:56.6 inches; FWAB: 37,229 lb/ac (Figure 11).

No differences were seen in germination, insect resistance, disease resistance, or canopy cover at 50% anthesis between the winter rye cultivars during the 2016/17 growing season (Table 13). Nearly all winter rye cultivars had reached 85-100% germination by 28 DAP, and 70-85% canopy cover with no insect damage by 50% anthesis. During the 2017/18 growing season, significant differences were seen in germination at 14 DAP with Guardian having lower germination (65-85%), than Hazlet, Olken, and Rymen (90-100%) using the Kruskal-Wallis one-way AOV and Dunn's All-Pairwise Comparisons Tests at the 5% level. There were significant differences in ranks between cultivar gemination at 7 and 28 DAP according to Kruskal-Wallis one-way analysis of variance, but no separation of the ranks was achieved with Dunn's all pairwise comparison test. All cultivars displayed slight to moderate disease damage from rust at the 50% anthesis evaluation during both years. Differences in the disease damage during the 2017/18 growing season were significant. Oklon showed slight damage, while Hazlet and Rymin had slightly-moderate disease damage.

Performance differences of the winter cereal rye cultivars may meet different conservation goals in California agricultural systems. Wheeler was both tall and produced the largest two-year average of FWAB and DM yield of the winter rye cultivars. However, tall cultivars may be more susceptible to lodging in areas that receive high winds in the spring and high residue cover crops can be challenging to manage. Brasetto was last to flower, was short, and had the lowest FWAB and DM yield production across both growing seasons.

***Crimson Clover***

Results from the crimson clover cultivars are shown in Tables 14, 15, and 16. Bloom dates are shown in Figure 12, while height versus FWAB, and TN versus DM yield are shown in Figures 13 and 14. Axes in Figures 13 and 14 represent the median of crimson clover cultivar data across two years and break the graphs into four quadrants.

The first cultivar to reach 50% bloom was AU Sunup, maturing in early April. AU Robin, AU Sunrise, Contea, and Dixie reached 50% bloom in mid-April, while Kentucky Pride was the last to bloom in late April/Early May (Figure 12). There were no significant differences in height the first growing season. During the second year, Kentucky Pride was significantly taller (27.6 inches) than all other evaluated cultivars using Tukey's HSD at the 5% level (Table 14). Contea was significantly shorter (15.8 inches) than AU Robin (21.7 inches) and AU Sunup (22.2 inches). No significant differences were seen in winter hardiness counts, or FWAB in either growing season. However, trends in the two-year averages of FWAB, DM yield, and TN content show that Dixie and Kentucky Pride could produce some of the highest TN yield estimates (213 lb/ac; 258 lb/ac, respectively) across the crimson clover cultivars, while AU Sunup had the lowest FWAB (31,211 lb/ac), DM yield (3639 lb/ac), and estimated TN yield (86 lb/ac) across both growing seasons (Figures 13 and 14).

In the ordinal data, significant differences were seen in germination across both years at 14 and 21 DAP, and in 2016/17 at 28 DAP. AU Sunrise emerged significantly faster (60-85% germination) than AU Sunup (30-60% in 2016/17; <30% in 2017/18) using the Kruskal-Wallis one-way AOV and Dunn's All-Pairwise Comparisons Tests at the 5% level (Table 16). Some significant differences were also seen in disease resistance and canopy cover at 50% bloom during the 2017/18 growing season. AU Robin and AU Sunrise showed no disease damage, while Contea and Dixie had slight damage in the form of spotting on leaves. AU Sunrise (76%) also had significantly more canopy cover than AU Sunup (47.5%) during the 2017/18 growing season. No differences were seen in canopy cover, or disease resistance (all slight) during the 2016/17 growing season. No significant differences were seen in germination at 7 DAP or insect resistance (only slight damage as a few holes in leaves) during either year.

These results indicate that there are some big differences between crimson clover cultivars. AU Sunup was the slowest to emerge and produced the lowest amount of biomass, but it was also the first cultivar to reach 50% bloom. Dixie and Kentucky Pride bloomed later in the season and had high DM yield and TN content, indicating that they could contribute large amounts of plant available nitrogen to a system.

***Daikon Radish***

Results from the daikon radish cultivars are shown in Tables 17, 18, and 19. Bloom dates are shown in Figure 15, while height versus FWAB, and TN versus DM yield are shown in Figures 16 and 17. Axes in Figures 16 and 17 represent the median of daikon radish cultivar data across two years and break the graphs into four quadrants.

The last daikon radish cultivar to reach 50% bloom was Graza, which occurred in early/mid-April (Figure 15). Concorde, Control, and Defender reached 50% bloom in late March, while the other daikon radish cultivars reached 50% bloom in mid-March. A significant difference in height during both years was shown using Tukey's HSD at the 5% level (Table 17). In the first growing season, the height of daikon radish cultivars ranged from 21 inches (Driller) to 43.3 inches tall (Control). During the second growing season only Defender (32.6 inches) and Graza (32.9 inches) were significantly taller than Tillage (24.3 inches). There were no significant differences in FWAB or winter hardiness counts during either year. Trends in the two-year average show that several of the cultivars, including Concorde (36.6 inches, 94,833 lb/ac), Control (37.3 inches, 75,026 lb/ac) and Defender (31.3 inches, 57,620 lb/ac), were both tall and had high FWAB (Figure 16). Other cultivars that matured in mid-March with biomass above the FWAB median (51,018 lb/ac) included Big Dog (63,623 lb/ac), Eco-Till (56,420 lb/ac), Groundhog (51,618 lb/ac), and Nitro (68,424 lb/ac) daikon radish. Average two-year trends also showed that Big Dog, Concorde, Control, Defender, Eco-Till and Nitro radish had both high DM yield and TN (Figure 17). However, Defender and Eco-Till, would be the only two cultivars that may contribute nitrogen, since their two-year average was above 3% (3.1% and 3.0%, respectively). The other cultivars may temporarily tie up nitrogen due to their lower TN content.

In the ordinal data, significant differences were seen in germination at 21, and 28 DAP, during both growing seasons using the Kruskal-Wallis one-way AOV and Dunn's All-Pairwise Comparisons Tests at the 5% level (Table 19). During both years, Graza emerged significantly later (30-60% in 2016/17; 60-65% in 2017/18) than Big Dog, Concorde, Eco-till, and Groundhog (65-85% in 2016/17; 90-100% in 2017/18). Significant differences were also seen in insect damage during the 2017/18 season with Lunch having significantly less damage (slight damage) than Concorde, Control and Defender (slightly-moderate). Insect damage was only slight to slightly-moderate with a few holes in leaves during both years. There were significant differences in ranks between cultivar gemination at 14 DAP, insect resistance, and canopy cover at 50% bloom in 2016/17, as well as cultivar gemination at 7 DAP in 2017/18, according to Kruskal-Wallis one-way analysis of variance, but no separation of the ranks was achieved with Dunn's all pairwise comparison test. No significant differences were seen in germination evaluations at 7 DAP in 2016/17, or 14 DAP and canopy cover at 50% bloom in 2017/18, or disease resistance during either year. Disease damage was slightly-moderate to moderate damage for all daikon radish cultivars with a few basal leaves showing discolored spotting.

Big Dog, Eco-Till, and Nitro were some of the first cultivars to reach 50% bloom, in mid-March, while Concorde, Control and Defender matured two weeks later. This information helps with timing and providing necessary windows for pollinator forage, as well as for termination timing. Big Dog, Concorde, and Eco-Till were also the earliest to germinate across both growing seasons indicating these may be good choices for weed competitors and erosion prevention. In terms of biomass and green manure potential, Big Dog, Concorde, Control, Defender, Eco-Till, and Nitro all had high FWAB, DM yield and relatively high TN content, but most of the daikon radish cultivars may temporarily tie up nitrogen due to their carbon to nitrogen ratio. Graza was the only late blooming cultivar that was tall, but slower to emerge. Driller, Lunch, Sodbuster Blend and Tillage had the lowest biomass and DM yield of the daikon radish cultivars.

***Hairy Vetch***

Results from the hairy vetch cultivars are shown in Tables 20, 21, and 22. Bloom dates are shown in Figure 18, while height versus FWAB, and TN versus DM yield are shown in Figures 19 and 20. Axes in Figures 19 and 20 represent the median of hairy vetch cultivar data across two years and break the graphs into four quadrants.

Lana vetch was the first hairy vetch cultivar to reach 50% bloom in late April/early May (Figure 18). Other evaluated hairy vetch cultivars reached 50% bloom during mid-May during both growing seasons. There were significant differences in height during the 2017/18 growing season with Purple Prosperity (34.1 inches) being significantly taller than TNT (27.2 inches) and Villana (28.2 inches) using Tukey's HSD at the 5% level (Table 20). No significant differences were seen the cultivar height during the 2016/17 growing season. No significant differences in FWAB or winter hardiness counts during either year. Trends in the two-year average of FWAB show that Purple Prosperity (49,306 lb/ac), TNT (46,959 lb/ac), and Villana (43,193 lb/ac) all had FWAB above the hairy vetch two-year median (42,287 lb/ac) (Figure 19). Numerical trends in the two-year average also show that TNT had the highest DM yield (9,052 lb/ac), and Lana had the highest TN across hairy vetch cultivars (4%) (Figure 20).

There were no significant differences between hairy vetch cultivars in the ordinal data (Table 22). There were significant differences in ranks between cultivar disease resistance in 2017/18, according to Kruskal-Wallis one-way analysis of variance, but no separation of the ranks was achieved with Dunn's all pairwise comparison test. All cultivars germinated at 60-85% at 28 DAP during both growing seasons. Disease damage was slight to moderate with a few spots on lower leaves, while insect damage was non-existent to slight with only a few holes in leaves. At 50% bloom, all hairy vetch cultivars had reached 85-95% canopy cover.

All hairy vetch cultivars performed similarly well in terms of good germination and canopy coverage as well as insect and disease resistance. Across the hairy vetch cultivars, Lana was the earliest to bloom and had the highest TN content. Purple Prosperity, TNT, and Villana produced the highest FWAB indicating these would also be good choices for green manure. TNT had the highest DM and estimated TN yield 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. Data was not collected for 50% bloom, height, FWAB, or TN. No significant differences were seen in winter hardiness counts between red clover cultivars. No significant differences were seen in any germination evaluations, insect or disease resistance, or percent canopy cover. Due to the late emergence and bloom dates in this trial, red clover may not be a good choice for a cool season cover crop in California. Conversely, as a component of a mixture for permanent tree crops where late bloom is desirable as a warm season cover crop for pollinators and beneficial insects, as well as nitrogen fixation, red clover may be underutilized in California.

## CONCLUSION

In general, most of the cover crop species and cultivars evaluated in this trial were well adapted to California's Central Valley during both the 2016/2017 and 2017/18 growing seasons. Red clover was the only exception. It did not fit into the cool season cover crop time frame for this area, but may have a better fit as a spring cover crop. Across the other seven species, there were some significant differences shown between cultivars in both growth characteristics and production.

The Austrian winter pea cultivars that produced the most biomass and estimated total nitrogen yield over the two years of data were Maxum, which blooms early (mid-March to mid-April) and Whistler, which blooms later (late April/early May). Clover cultivars suitable for green manure included Fixation balansa clover, and 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, as well as several daikon radish cultivars including Big, Dog, Concorde, Control, Defender, Eco-Till, and Nitro. Graza daikon radish may not be the best cultivar choice for weed competition in this area, due to slower emergence. Successful cereal cover crops and cultivars that produced large amounts of biomass included Soil Saver black oat, Cosaque black seeded oat, 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.

Next steps include, developing U.S. regional recommendations for cover crop cultivars to be based on these final results. Effective cover crop cultivars will also need further evaluation in relation to different areas within California and for specific farming operations to estimate their compatibility and success with different agricultural systems and practices.

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**Table 2.** Austrian winter pea cultivar average quantitative measurements at 50% bloom including days after planting, height, and fresh weight aboveground biomass collected at the Lockeford Plant Materials Center, CA 2016/17 and 2017/18.

| | 2016/2017 | | | | 2017/2018 | | | |
|---|---|---|---|---|---|---|---|---|
| Cultivar | DAP | Height | | Fresh Weight Aboveground Biomass | DAP | Height | | Fresh Weight Aboveground Biomass |
| | | ——in—— | | ———lb/ac——— | | ——in—— | | ———lb/ac——— |
| Arvica 4010 | 128 | 23.8 | ab* | 18,006 | 181 | 14.0 | a | 4,008 |
| Dunn | 129 | 20.7 | b | 17,606 | N/A | N/A | N/A | N/A |
| Frost Master | 175 | 23.5 | ab | 24,008 | 197 | 19.3 | a | N/A |
| Lynx | 175 | 17.5 | b | 14,405 | 193 | 16.2 | a | 11,892 |
| Maxum | 129 | 20.3 | b | 27,610 | 181 | 14.6 | a | 10,193 |
| Survivor 15 | 188 | 30.8 | a | 18,006 | 206 | 25.8 | a | 9,648 |
| Whistler | 174 | 21.0 | b | 25,209 | 193 | 17.1 | a | 54,995 |
| Windham | 175 | 18.0 | b | 10,804 | 193 | 14.3 | a | 15,660 |
| Mean | 160 | 22.0 | | 19,517 | 192 | 17.3 | | 17,733 |
| Std. dev# | 24 | 5.3 | | 13,291 | 8 | 4.7 | | 20,010 |

#Standard deviation

*Means in columns followed by the same letters are not significantly different at $P<0.05$.

All measurements were collected at 50% bloom.

DAP = days after planting; in = inches; lb/ac = pounds/acre.

**Table 3.** Austrian winter pea cultivar average dry matter percent, total percent nitrogen, estimated dry matter yield, and total nitrogen yield collected at the Lockeford Plant Materials Center, CA 2016/17 and 2017/18.

| | 2016/2017 | | | | 2017/2018 | | | |
|---|---|---|---|---|---|---|---|---|
| Cultivar | DM | Total N | Estimated DM Yield | Estimated Total N Yield | DM | Total N | Estimated DM Yield | Estimated Total N Yield |
| | ———%——— | | ——lb/ac—— | ——lb/ac—— | ———%——— | | ——lb/ac—— | ——lb/ac—— |
| Arvica 4010 | 17.7 | 2.5 | 3,183 | 79 | 33.7 | 3.2 | 1,351 | 43 |
| Dunn | 16.8 | 3.0 | 2,958 | 89 | N/A | N/A | N/A | N/A |
| Frost Master | 23.9 | 2.8 | 5,733 | 160 | N/A | N/A | N/A | N/A |
| Lynx | 14.5 | 4.1 | 2,083 | 85 | 23.4 | 3.5 | 2,783 | 98 |
| Maxum | 13.4 | 3.8 | 3,703 | 142 | 25.9 | 3.5 | 2,640 | 93 |
| Survivor 15 | 24.5 | 2.7 | 4,417 | 118 | 33.2 | 3.2 | 3,203 | 102 |
| Whistler | 14.7 | 2.8 | 3,711 | 105 | 19.2 | 3.8 | 10,559 | 402 |
| Windham | 19.1 | 3.5 | 2,065 | 73 | 26.8 | 3.4 | 4,197 | 141 |
| Mean | 18.1 | 3.2 | 3,482 | 106 | 27.0 | 3.4 | 4,124 | 147 |
| Std. dev# | 4.2 | 0.6 | 1,138 | 29 | 5.6 | 0.2 | 3,000 | 118 |

#Standard deviation

DM and N were measurements of composite samples collected at 50% bloom.

Est. DM Calculation: Fresh Weight Aboveground Biomass x (DM/100)

Est. Total N Yield Calculation: (Total N/100) x DM Yield

DM = dry matter, N = nitrogen, lb/ac = pounds/acre.

**Table 4.** Austrian winter pea cultivar average ordinal data including average germination at 7, 14, 21, and 28 days after planting, insect and disease resistance, and canopy cover at 50% bloom collected at the Lockeford Plant Materials Center, CA 2016/17 and 2017/18.

| | 2016/2017 | | | | | | | | | 2017/2018 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cultivar | Germination[¥] | | | | Insect Resistance[£] | Disease Resistance[£] | | Canopy Cover[§] | | Germination[¥] | | | | Insect Resistance[£] | Disease Resistance[£] | | Canopy Cover[§] | |
| | 7 DAP | 14 DAP | 21 DAP | 28 DAP | ———50% Bloom——— | | | | | 7 DAP | 14 DAP | 21 DAP | 28 DAP | ———50% Bloom——— | | | | |
| Arvica 4010 | 0.0 | 1.3[¢] | 2.0[¢] | 2.0[¢] | 1.0 | 2.0 | a* | 71.3 | a | 0.0 | 2.5[¢] | 3.0[¢] | 3.0 | 1.0 | 5.0 | a | 19.0 | b |
| Dunn | 0.5 | 1.8 | 2.0 | 2.0 | 1.0 | 3.0 | a | 69.7 | a | 0.0 | 2.8 | 3.0 | 3.0 | N/A | N/A | N/A | N/A | N/A |
| Frost Master | 0.3 | 1.3 | 1.3 | 1.3 | 1.0 | 2.8 | a | 52.3 | a | 0.0 | 2.0 | 2.5 | 2.5 | 2.0 | 4.0 | ab | 42.8 | ab |
| Lynx | 0.3 | 0.8 | 1.0 | 1.0 | 1.3 | 2.0 | a | 42.8 | a | 0.0 | 2.0 | 2.3 | 2.5 | 2.0 | 2.3 | b | 47.5 | ab |
| Maxum | 0.3 | 1.8 | 2.0 | 2.0 | 2.0 | 2.5 | a | 66.5 | a | 0.0 | 2.5 | 3.0 | 3.0 | 1.0 | 5.0 | a | 23.8 | b |
| Survivor 15 | 0.5 | 1.8 | 2.0 | 2.0 | 2.0 | 2.0 | a | 61.8 | a | 0.0 | 3.0 | 3.0 | 3.0 | 2.0 | 3.0 | ab | 57.0 | ab |
| Whistler | 0.3 | 1.0 | 1.3 | 1.3 | 1.0 | 2.5 | a | 47.5 | a | 0.0 | 2.0 | 3.0 | 3.0 | 2.0 | 2.3 | b | 76.0 | a |
| Windham | 0.3 | 1.3 | 1.3 | 1.3 | 1.0 | 2.0 | a | 42.8 | a | 0.0 | 2.0 | 2.5 | 2.8 | 2.0 | 3.0 | ab | 57.0 | ab |
| Mean | 0.3 | 1.3 | 1.6 | 1.6 | 1.3 | 2.3 | | 56.8 | | 0.0 | 2.3 | 2.8 | 2.8 | 1.7 | 3.5 | | 42.7 | |
| Std. dev[#] | 0.5 | 0.5 | 0.5 | 0.5 | 0.8 | 0.5 | | 17.3 | | 0.0 | 0.5 | 0.4 | 0.4 | 0.5 | 1.1 | | 21.6 | |

[#]Standard deviation

*Means in columns followed by the same letters are not significantly different at $P<0.05$.

[¢]There were significant differences in ranks between cultivars according to Kruskal-Wallis one-way analysis of variance, but no separation of the ranks was achieved with Dunn's all pairwise comparison test.

[¥]Germination rated on the following scale: 0=poor (<25% germination), 1=moderate (30-60%), 2=good (65-85%), 3=excellent (90-100%).

[£]Disease/Insect Resistance rated on the following scale: 0=no damage, 1=slight damage, 3=moderate damage, 5=severe damage.

[§]Canopy Cover rated as a visual estimate of the percentage of ground covered by the seeded species.

DAP = days after planting.

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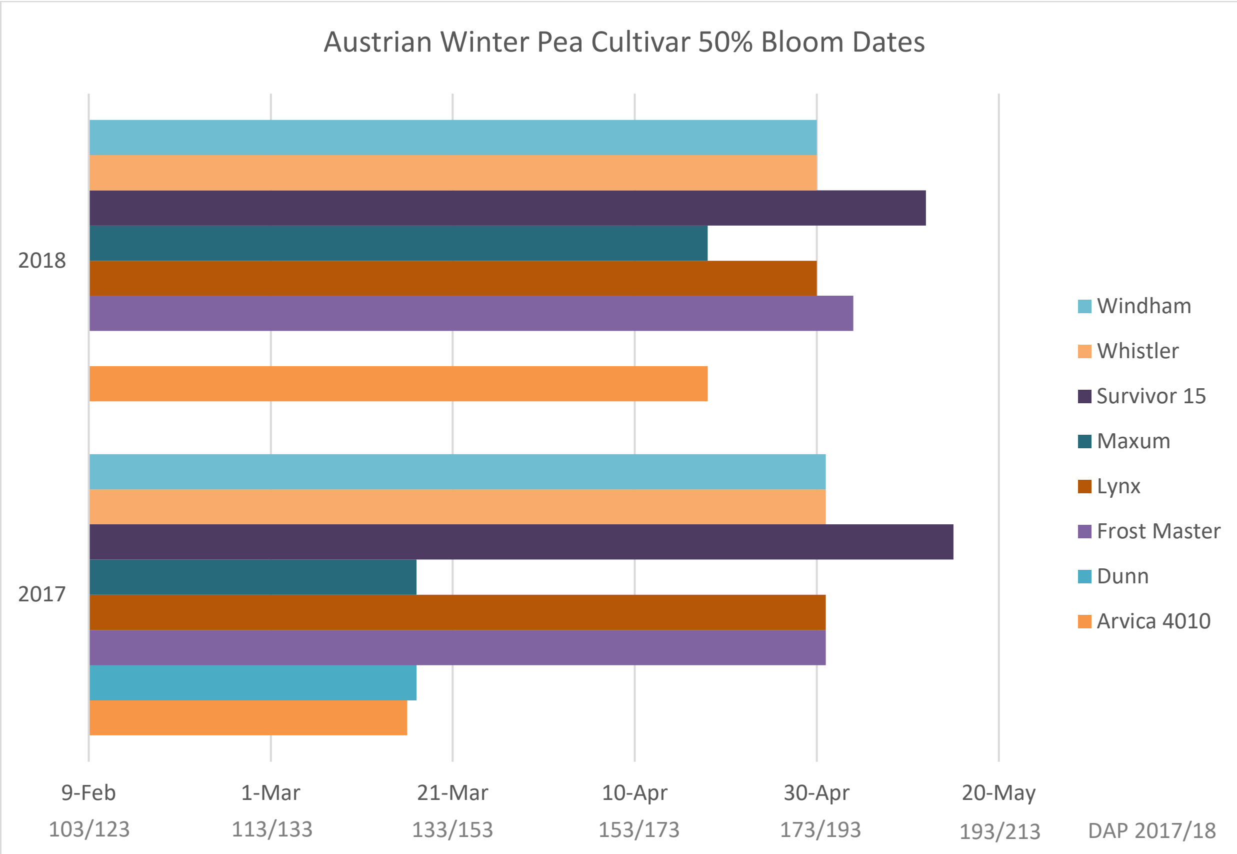


**Figure 2**. Differences between 50% bloom dates of Austrian winter pea cultivars across two growing seasons. The 50% bloom date indicates maximum nitrogen content of the cover crop. DAP = Days after planting. Planting dates for 2017 were two weeks earlier than in 2016. Arvica 4010 and Maxum, were two of the first to bloom, while Survivor 15 was last during both years.

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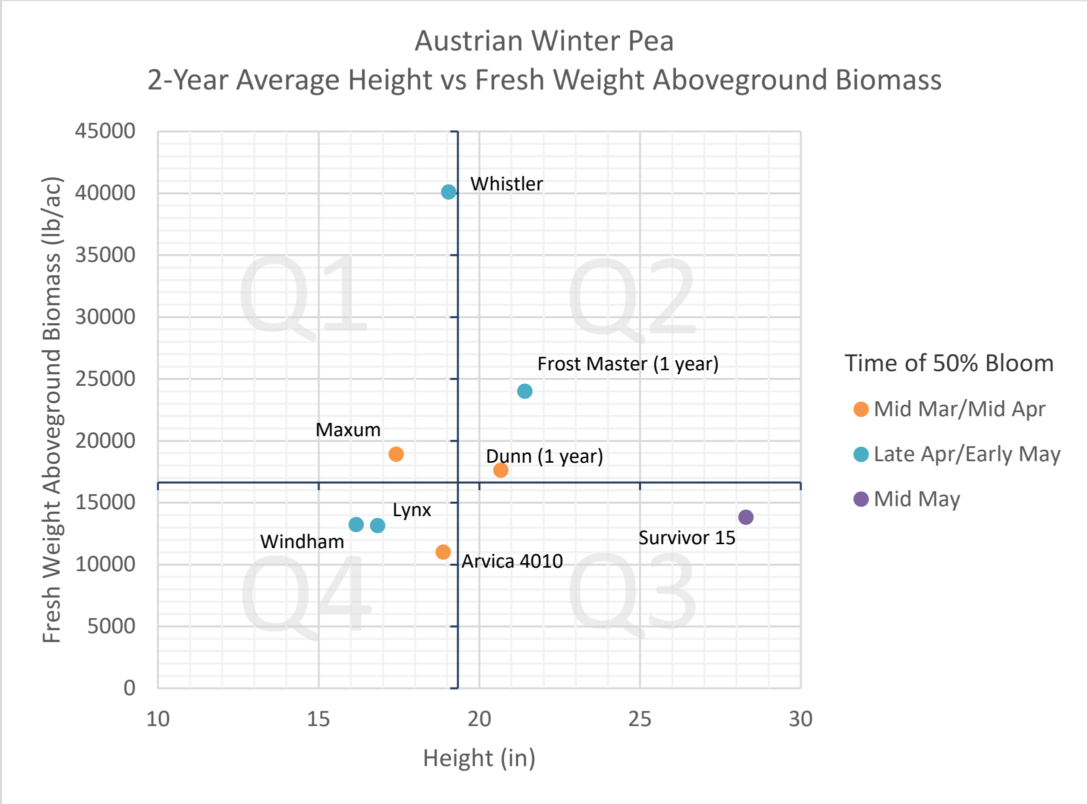


**Figure 3**. Differences shown between Austrian winter pea cultivars across a two-year average height versus fresh weight aboveground biomass (FWAB) at 50% bloom. Axes represent the median of height data (19.3 inches) and FWAB data (16,633 lb/ac) and break the graph into four quadrants. In the resulting quadrants Q1 = shorter height, but high biomass, Q2 = tall with high biomass, Q3 = tall with low biomass, and Q4 = short and have low biomass. Maxum and Whistler both had FWAB above the median. Dunn and Frost Master did not survive the 2018 growing season.

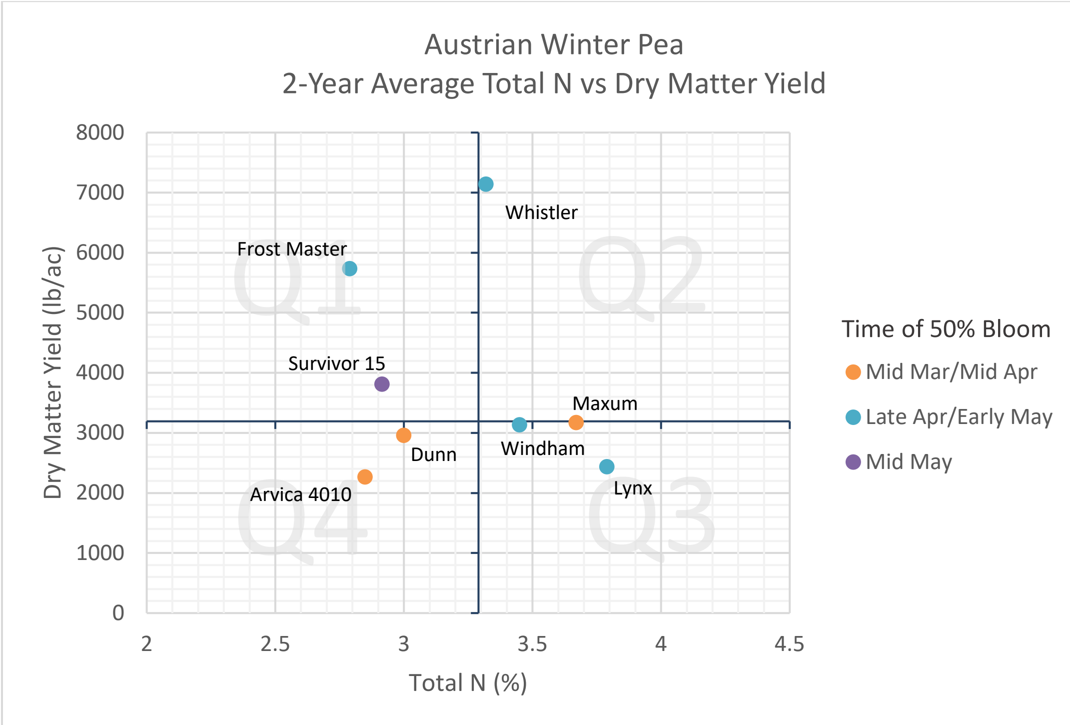


**Figure 4.** Differences shown in estimated total nitrogen (TN) yield between Austrian winter pea cultivars across a two-year average of TN versus dry matter (DM) yield at 50% bloom. Axes represent the median TN data (3.3%) and DM yield data (3,192 lb/ac) and break the graph into four quadrants. In the resulting quadrants Q1 = high DM, but low TN, Q2 = high DM and high TN translating to high estimated TN yield, Q3 = low DM, but high TN, and Q4 = both low DM and low TN. Lynx, Maxum, and Windham were above the median TN content, while Whistler was high in both TN and DM yield.

**Table 5.** Balansa clover cultivar average quantitative measurements at 50% bloom including days after planting, height, and fresh weight aboveground biomass collected at the Lockeford Plant Materials Center, CA 2016/17 and 2017/18.

| | 2016/2017 | | | | 2017/2018 | | | |
|---|---|---|---|---|---|---|---|---|
| Cultivar | DAP | Height | | Fresh Weight Aboveground Biomass | DAP | Height | | Fresh Weight Aboveground Biomass |
| | | —in— | | ——lb/ac—— | | —in— | | ——lb/ac—— |
| Fixation | 174 | 21.0 | a* | 62,422 | 193 | 18.8 | a | 15,943 |
| Frontier | 139 | 10.5 | b | 13,204 | 168 | 10.3 | a | 8,403 |
| Mean | 157 | 15.8 | | 37,813 | 181 | 14.6 | | 12,173 |
| Std. dev# | 19 | 7.2 | | 41,420 | 13 | 5.3 | | 7,153 |

#Standard deviation

*Means in columns followed by the same letters are not significantly different at *P*<0.05.

All measurements were collected at 50% bloom.

DAP = days after planting; in = inches; lb/ac = pounds/acre.

**Table 6.** Balansa clover cultivar average dry matter percent, total percent nitrogen, estimated dry matter yield and total nitrogen yield collected at the Lockeford Plant Materials Center, CA 2016/17 and 2017/18.

| | 2016/2017 | | | | 2017/2018 | | | |
|---|---|---|---|---|---|---|---|---|
| Cultivar | DM | Total N | Estimated DM Yield | Estimated Total N Yield | DM | Total N | Estimated DM Yield | Estimated Total N Yield |
| | ——%—— | | —lb/ac— | —lb/ac— | ——%—— | | —lb/ac— | —lb/ac— |
| Fixation | 11.8 | 2.0 | 7,335 | 143 | 14.6 | 3.4 | 2,328 | 79 |
| Frontier | 8.9 | 3.0 | 1,175 | 35 | 13.2 | 2.9 | 1,109 | 32 |
| Mean | 10.3 | 2.5 | 4,257 | 89 | 13.9 | 3.2 | 1,720.0 | 56 |
| Std. dev# | 2.0 | 0.7 | 4,356 | 77 | 1.0 | 0.4 | 862 | 33 |

#Standard deviation

DM and N were measurements of composite samples collected at 50% bloom.

Est. DM Calculation: Fresh Weight Aboveground Biomass x (DM/100)

Est. Total N Yield Calculation: (Total N/100) x DM Yield

DM = dry matter, N = nitrogen, lb/ac = pounds/acre.

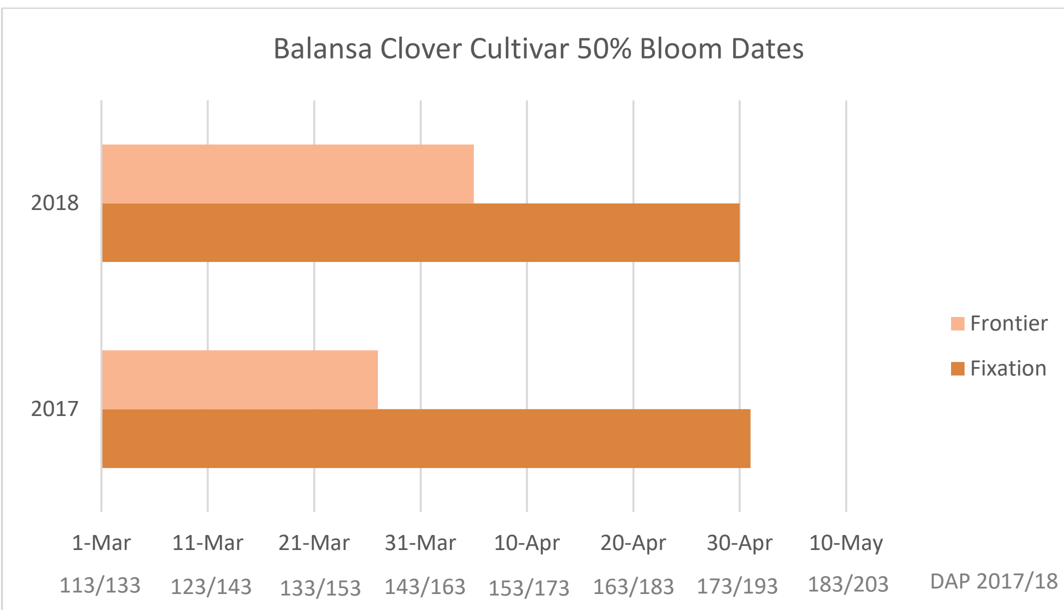


**Figure 5**. Balansa clover cultivar 50% bloom dates across two growing seasons. The 50% bloom date indicates maximum nitrogen content of the cover crop. DAP = Days after planting. Planting dates for 2017 were two weeks earlier than in 2016. Frontier was the first to bloom during both years.

**Table 7.** Balansa clover cultivar average ordinal data including average germination at 7, 14, 21, and 28 days after planting, insect resistance and canopy cover at 50% bloom collected at the Lockeford Plant Materials Center, CA 2016/17 and 2017/18.

| | 2016/2017 | | | | | | | | | | | 2017/2018 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cultivar | Germination[¥] | | | | | | | | Insect Resistance[£] | | Canopy Cover[§] | Germination[¥] | | | | | | | | Insect Resistance[£] | | Canopy Cover[§] |
| | 7 DAP | | 14 DAP | | 21 DAP | | 28 DAP | | ——50% Bloom—— | | | 7 DAP | | 14 DAP | | 21 DAP | | 28 DAP | | ——50% Bloom—— | | |
| Fixation | 0.0 | a* | 1.5 | a | 1.8 | a | 1.8 | a | 1.8 | a | 57.0 | 0.0 | a | 0.0 | a | 0.0 | a | 0.0 | a | 2.0 | a | 47.5 |
| Frontier | 0.0 | a | 0.0 | b | 0.5 | b | 0.5 | b | 1.0 | b | 47.5 | 0.0 | a | 0.0 | a | 0.0 | a | 0.0 | a | 1.3 | b | 38.0 |
| Mean | 0.0 | | 0.8 | | 1.1 | | 1.1 | | 1.4 | | 52.3 | 0.0 | | 0.0 | | 0.0 | | 0.0 | | 1.6 | | 42.8 |
| Std. dev[#] | 0.0 | | 0.9 | | 0.8 | | 0.8 | | 0.5 | | 16.8 | 0.0 | | 0.0 | | 0.0 | | 0.0 | | 0.5 | | 16.8 |

[#]Standard deviation

*Means in columns followed by the same letters are not significantly different at $P$<0.05.

[c]There were significant differences in ranks between cultivars according to Kruskal-Wallis one-way analysis of variance, but no separation of the ranks was achieved with Dunn's all pairwise comparison test.

[¥]Germination rated on the following scale: 0=poor (<25% germination), 1=moderate (30-60%), 2=good (65-85%), 3=excellent (90-100%).

[£]Insect Resistance rated on the following scale: 0=no damage, 1=slight damage, 3=moderate damage, 5=severe damage.

[§]Canopy Cover rated as a visual estimate of the percentage of ground covered by the seeded species.

DAP = days after planting.

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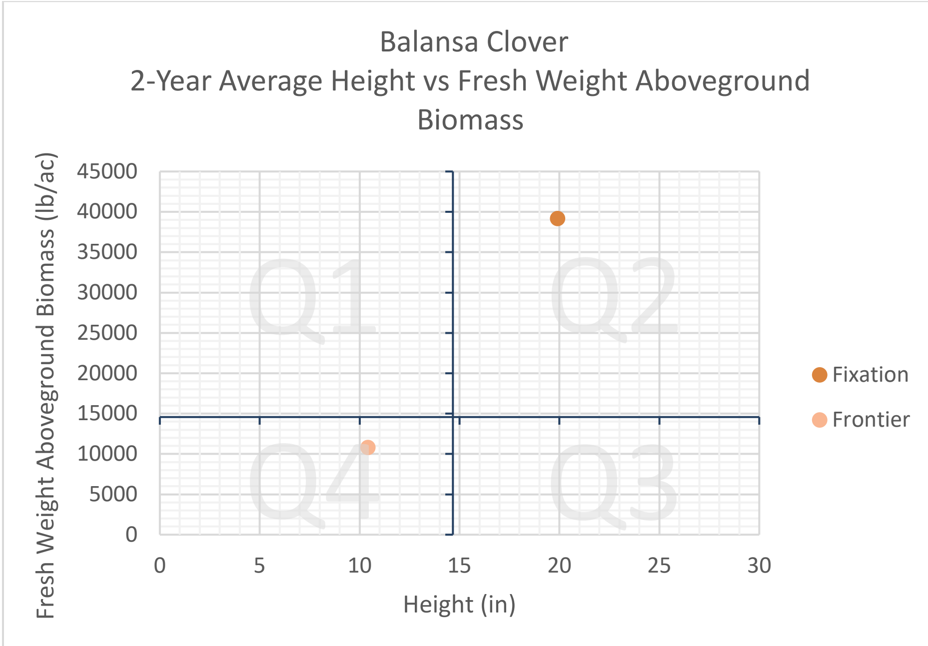


**Figure 6**. Differences shown between balansa clover cultivars across a two-year average of height versus fresh weight aboveground biomass (FWAB) at 50% bloom. Axes represent the median height data (14.7 inches) and FWAB data (14,574 lb/ac) and break the graph into four quadrants. In the resulting quadrants Q1 = shorter height, but high biomass, Q2 = tall with high biomass, Q3 = tall with low biomass, and Q4 = short and have low biomass. Fixation was both tall and had high FWAB.

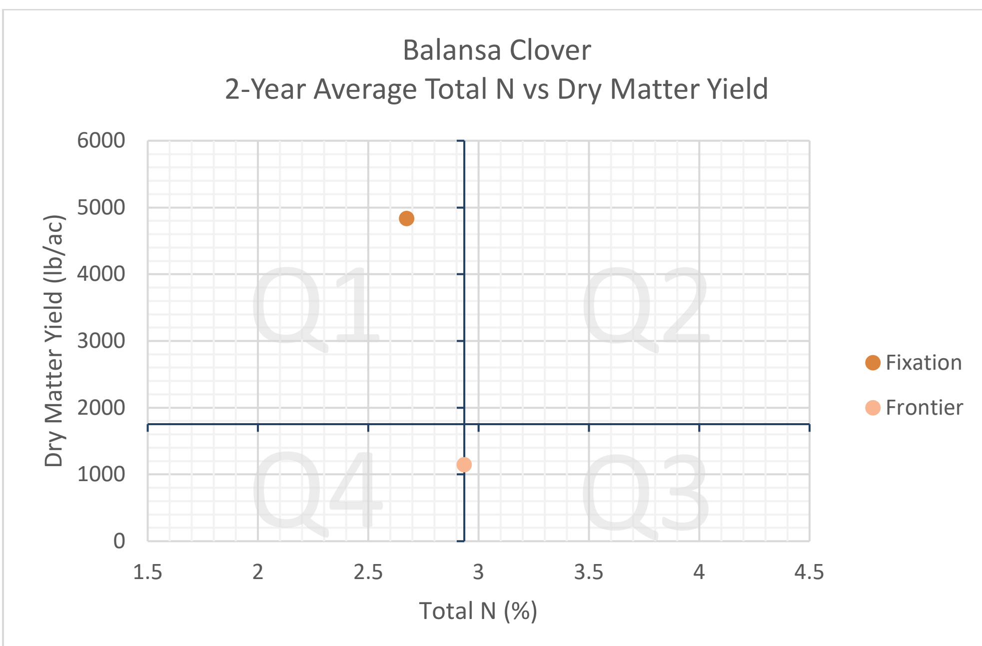


**Figure 7.** Differences shown in estimated total nitrogen (TN) yield between balansa clover cultivars across a two-year average of TN versus dry matter (DM) yield at 50% bloom. Axes represent the median TN data (2.9 %) and DM yield data (1,754 lb/ac) and break the graph into four quadrants. In the resulting quadrants Q1 = high DM, but low TN, Q2 = high DM and high TN translating to high estimated TN yield, Q3 = low DM, but high TN, and Q4 = both low DM and low TN. Fixation had more DM yield then Frontier.

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**Table 8.** Black oat (Soil Saver) and black seeded oat (Cosaque) cultivar average quantitative measurements at 50% anthesis including days after planting, height, and fresh weight aboveground biomass collected at the Lockeford Plant Materials Center, CA 2016/17 and 2017/18.

| | 2016/2017 | | | | 2017/2018 | | | |
|---|---|---|---|---|---|---|---|---|
| Cultivar | DAP | Height | | Fresh Weight Aboveground Biomass | DAP | Height | | Fresh Weight Aboveground Biomass |
| | | —in— | | ——lb/ac—— | | —in— | | ——lb/ac—— |
| Cosaque | 182 | 41.0 | b* | 88,831 | 204 | 31.0 | b | 34,129 |
| Soil Saver | 182 | 53.5 | a | 52,818 | 187 | 34.8 | a | 24,655 |
| Mean | 182 | 47.3 | | 70,825 | 196 | 32.9 | | 29,392 |
| Std. dev# | 0 | 7.0 | | 51,123 | 9 | 2.7 | | 7,106 |

#Standard deviation

*Means in columns followed by the same letters are not significantly different at $P<0.05$.

All measurements were collected at 50% bloom.

DAP = days after planting; in = inches; lb/ac = pounds/acre.

**Table 9.** Black oat (Soil Saver) and black seeded oat (Cosaque) cultivar average dry matter percent, total percent nitrogen, and estimated dry matter yield collected at the Lockeford Plant Materials Center, CA 2016/17 and 2017/18.

| | 2016/2017 | | | 2017/2018 | | |
|---|---|---|---|---|---|---|
| Cultivar | DM | Total N | Estimated DM Yield | DM | Total N | Estimated DM Yield |
| | ———%——— | | ——lb/ac—— | ———%——— | | ——lb/ac—— |
| Cosaque | 22.6 | 1.5 | 20,049 | 30.3 | 0.9 | 10,341 |
| Soil Saver | 25.6 | 1.1 | 13,511 | 28.9 | 0.9 | 7,125 |
| Mean | 24.1 | 1.3 | 16,778 | 29.6 | 0.9 | 8,734 |
| Std. dev# | 2.1 | 0.3 | 4,621 | 1.0 | 0.0 | 7,928 |

#Standard deviation

DM and N were measurements of composite samples collected at 50% bloom.

Est. DM Calculation: Fresh Weight Aboveground Biomass x (DM/100)

DM = dry matter, N = nitrogen, lb/ac = pounds/acre.

**Table 10.** Black oat (Soil Saver) and black seeded oat (Cosaque) and black seeded oat cultivar average ordinal data including average germination at 7, 14, 21, and 28 days after planting, disease resistance and canopy cover at 50% anthesis collected at the Lockeford Plant Materials Center, CA 2016/17 and 2017/18.

| Cultivar | 2016/2017 Germination[¥] | | | | 2016/2017 Disease Resistance[£] | | 2016/2017 Canopy Cover[§] | | 2017/2018 Germination[¥] | | | | 2017/2018 Disease Resistance[£] | | 2017/2018 Canopy Cover[§] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7 DAP | 14 DAP | 21 DAP | 28 DAP | ––50% Anthesis–– | | | | 7 DAP | 14 DAP | 21 DAP | 28 DAP | ––50% Anthesis–– | | | |
| Cosaque | 1.8 | 2.5 | 2.5 | 2.5 | 2.5 | a* | 76.0 | b | 0.0 | 0.3 | 1.0 | 1.5 | 1.0 | a | 95.0 | a |
| Soil Saver | 1.5 | 3.0 | 3.0 | 3.0 | 1.0 | b | 90.3 | a | 0.0 | 0.8 | 1.5 | 2.0 | 1.0 | a | 95.0 | a |
| Mean | 1.6 | 2.8 | 2.8 | 2.8 | 1.8 | | 83.1 | | 0.0 | 0.5 | 1.3 | 1.8 | 1.0 | | 95.0 | |
| Std. dev[#] | 0.5 | 0.5 | 0.5 | 0.5 | 0.9 | | 9.8 | | 0.0 | 0.8 | 0.7 | 0.5 | 0.0 | | 0.0 | |

[#]Standard deviation

*Means in columns followed by the same letters are not significantly different at $P$<0.05.

[ϲ]There were significant differences in ranks between cultivars according to Kruskal-Wallis one-way analysis of variance, but no separation of the ranks was achieved with Dunn's all pairwise comparison test.

[¥]Germination rated on the following scale: 0=poor (<25% germination), 1=moderate (30-60%), 2=good (65-85%), 3=excellent (90-100%).

[£]Disease Resistance rated on the following scale: 0=no damage, 1=slight damage, 3=moderate damage, 5=severe damage.

[§]Canopy Cover rated as a visual estimate of the percentage of ground covered by the seeded species.

DAP = days after planting.

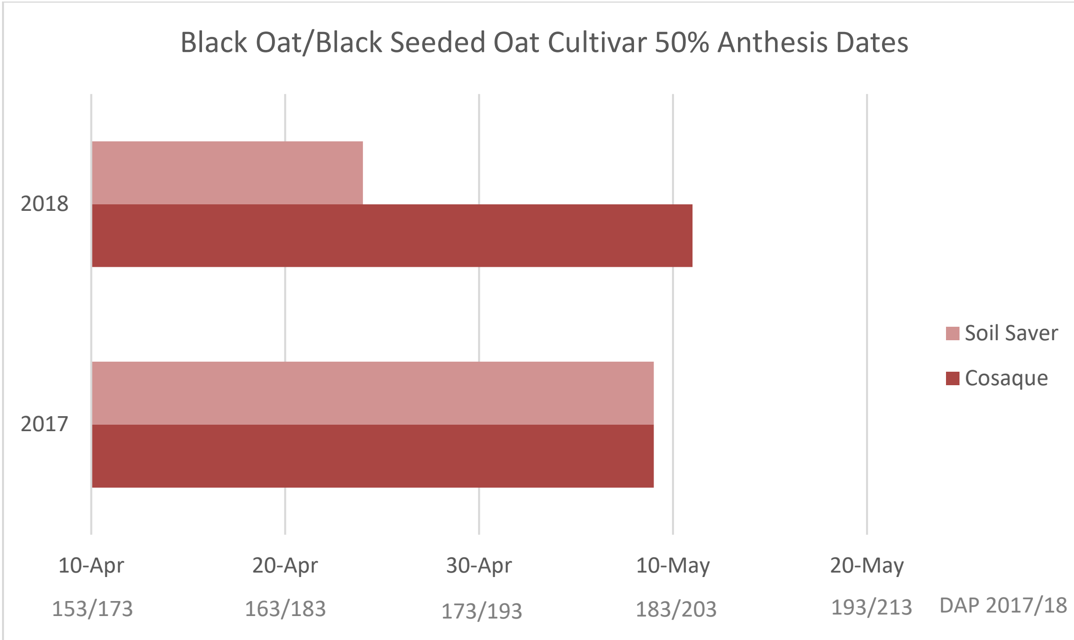


**Figure 8**. Differences between 50% anthesis dates of black oat (Soil Saver) and black seeded oat (Cosaque) cultivars across two growing seasons. DAP = Days after planting. Planting dates for 2017 were two weeks earlier than in 2016. Soil Saver was the first to bloom during the second season, while Cosaque reached maturity in May of both years.

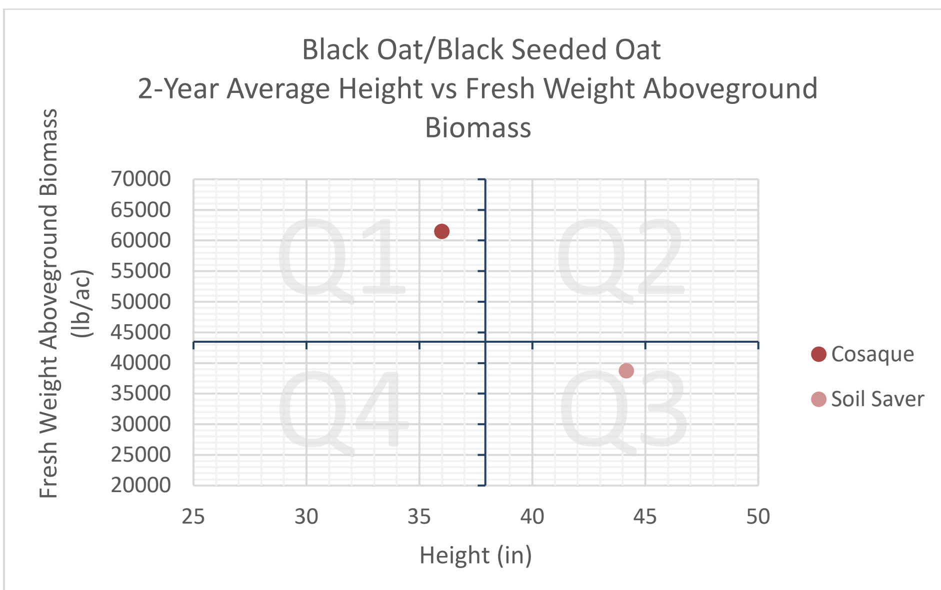


**Figure 9**. Differences shown between black oat (Soil Saver) and black seeded oat (Cosaque) cultivars across a two-year average of height versus fresh weight aboveground biomass (FWAB) at 50% anthesis. Axes represent the median of height data (37.9 inches) and FWAB data over two years (43,474 lb/ac) and break the graph into four quadrants. In the resulting quadrants Q1 = shorter height, but high biomass, Q2 = tall with high biomass, Q3 = tall with low biomass, and Q4 = short and have low biomass. Soil Saver was tall and Cosaque had high FWAB.

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**Table 11.** Cereal rye cultivar average quantitative measurements at 50% anthesis including days after planting, height, and fresh weight aboveground biomass collected at the Lockeford Plant Materials Center, CA 2016/17 and 2017/18.

| | 2016/2017 | | | | | 2017/2018 | | | |
|---|---|---|---|---|---|---|---|---|---|
| Cultivar | DAP | Height | | Fresh Weight Aboveground Biomass | | DAP | Height | | Fresh Weight Aboveground Biomass |
| Spring Cereal Rye | | —in— | | ———lb/ac——— | | | —in— | | ———lb/ac——— |
| Florida 401 | 140 | 57.3 | a | 43,215 | a | 155 | 46.9 | a | 21,607 |
| Merced | 140 | 48.8 | a | 44,415 | a | 155 | 45.7 | a | 20,407 |
| Aroostook | 161 | 52.8 | a | 37,213 | a | 173 | 66.2 | a | 23,958 |
| Bates | 161 | 55.0 | a | 50,418 | a | 172 | 70.8 | a | 35,196 |
| Elbon | 161 | 53.8 | a | 64,823 | a | 177 | 64.3 | a | 37,244 |
| Maton | 161 | 57.3 | a | 51,618 | a | 172 | 68.7 | a | 27,269 |
| Maton II | 161 | 56.0 | a | 54,019 | a | 174 | 67.3 | a | 28,554 |
| Wintergrazer 70 | 160 | 58.3 | a | 49,217 | a | 174 | 65.0 | a | 34,848 |
| Wrens Abruzzi | 158 | 55.0 | a | 52,818 | a | 171 | 71.6 | a | 27,269 |
| Mean | 156 | 54.9 | | 49,751 | | 169 | 62.9 | | 28,484 |
| Std. dev[#] | 9 | 3.9 | | 16,797 | | 8 | 9.8 | | 8,992 |

| | 2016/2017 | | | | | 2017/2018 | | | |
|---|---|---|---|---|---|---|---|---|---|
| Cultivar | DAP | Height | | Fresh Weight Aboveground Biomass | | DAP | Height | | Fresh Weight Aboveground Biomass |
| Winter Cereal Rye | | —in— | | ———lb/ac——— | | | —in— | | ———lb/ac——— |
| Brasetto | 182 | 40.8 | c | 22,808 | b | 192 | 34.4 | c | 26,746 |
| Guardian | 176 | 58.5 | ab | 54,019 | a | 194 | 49.7 | b | 22,477 |
| Hazlet | 176 | 50.8 | b | 42,015 | ab | 192 | 44.1 | b | 28,575 |
| Oklon | 174 | 61.0 | a | 38,413 | ab | 182 | 64.7 | a | 26,681 |
| Rymin | 176 | 55.8 | ab | 57,620 | a | 193 | 50.4 | b | 29,730 |
| Wheeler | 176 | 63.0 | a | 67,224 | a | 192 | 62.9 | a | 38,594 |
| Mean | 177 | 55.0 | | 47,016 | | 191 | 51.0 | | 28,800 |
| Std. dev[#] | 3 | 8.3 | | 24,483 | | 4 | 11.1 | | 8,803 |

[#]Standard deviation

*Means in columns followed by the same letters are not significantly different at *P*<0.05.

All measurements were collected at 50% bloom.

DAP = days after planting; in = inches; lb/ac = pounds/acre.

**Table 12.** Cereal rye cultivar average dry matter percent, total percent nitrogen, and estimated dry matter yield collected at the Lockeford Plant Materials Center, CA 2016/17 and 2017/18.

| | 2016/2017 | | | 2017/2018 | | |
|---|---|---|---|---|---|---|
| Cultivar | DM | Total N | Estimated DM Yield | DM | Total N | Estimated DM Yield |
| Spring Cereal Rye | ——%—— | | ——lb/ac—— | ——%—— | | ——lb/ac—— |
| Florida 401 | 28.2 | 1.1 | 12,187 | 32.1 | 1.3 | 6,936 |
| Merced | 22.5 | 1.4 | 9,993 | 37.4 | 1.0 | 7,632 |
| Aroostook | 25.6 | 0.6 | 9,527 | 27.6 | 1.0 | 6,612 |
| Bates | 27.2 | 0.7 | 13,713 | 34.2 | 1.0 | 12,037 |
| Elbon | 25.3 | 1.2 | 16,400 | 33.5 | 0.8 | 12,477 |
| Maton | 28.3 | 1.0 | 14,608 | 29.2 | 0.9 | 7,963 |
| Maton II | 29.9 | 0.9 | 16,152 | 33.3 | 0.7 | 9,508 |
| Wintergrazer 70 | 30.2 | 0.8 | 14,864 | 29.1 | 1.2 | 10,141 |
| Wrens Abruzzi | 28.1 | 0.9 | 14,842 | 32.5 | 1.1 | 8,862 |
| Mean | 27.3 | 1.0 | 13587 | 32.1 | 1.1 | 9130 |
| Std. dev[#] | 2.4 | 0.3 | 2503 | 3.0 | 0.4 | 2111 |
| | 2016/2017 | | | 2017/2018 | | |
| Cultivar | DM | Total N | Estimated DM Yield | DM | Total N | Estimated DM Yield |
| Winter Cereal Rye | ——%—— | | ——lb/ac—— | ——%—— | | ——lb/ac—— |
| Brasetto | 34.8 | 0.7 | 7,937 | 29.3 | 0.9 | 7,837 |
| Guardian | 26.8 | 1.2 | 14,477 | 27.3 | 1.0 | 6,136 |
| Hazlet | 28.3 | 0.8 | 11,890 | 27.7 | 0.9 | 7,915 |
| Oklon | 40.4 | 0.8 | 15,519 | 32.8 | 1.2 | 8,751 |
| Rymin | 29.9 | 0.6 | 17,228 | 28.8 | 1.6 | 8,562 |
| Wheeler | 26.9 | 0.8 | 18,083 | 28.4 | 0.8 | 10,961 |
| Mean | 31.2 | 0.8 | 14189 | 29.1 | 1.1 | 8360 |
| Std. dev[#] | 5.4 | 0.2 | 3758 | 2.0 | 0.3 | 1573 |

[#]Standard deviation

DM and N were measurements of composite samples collected at 50% bloom.

Est. DM Calculation: Fresh Weight Aboveground Biomass x (DM/100)

DM = dry matter, N = nitrogen, lb/ac = pounds/acre.

**Table 13.** Cereal rye cultivar average ordinal data including average germination at 7, 14, 21, and 28 days after planting, disease resistance and canopy cover at 50% anthesis collected at the Lockeford Plant Materials Center, CA 2016/17 and 2017/18.

| | 2016/2017 | | | | | | 2017/2018 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cultivar | Germination[¥] | | | | Disease Resistance[£] | Canopy Cover[§] | Germination[¥] | | | | Disease Resistance[£] | Canopy Cover[§] |
| Spring Cereal Rye | 7 DAP | 14 DAP | 21 DAP | 28 DAP | ——50% Anthesis—— | | 7 DAP | 14 DAP | 21 DAP | 28 DAP | ——50% Anthesis—— | |
| Florida 401 | 3.0 | 3.0 | 3.0 | 3.0 | 2.0[¢] | 95.0 | 1.8 ab | 2.3 | 3.0 | 3.0 | 4.0 a | 95.0 |
| Merced | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 95.0 | 1.8 ab | 2.8 | 3.0 | 3.0 | 4.0 a | 95.0 |
| Aroostook | 3.0 | 3.0 | 3.0 | 3.0 | 2.3 | 80.8 | 3.0 a | 3.0 | 3.0 | 3.0 | 1.5 ab | 95.0 |
| Bates | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 90.3 | 2.3 ab | 3.0 | 3.0 | 3.0 | 2.0 ab | 95.0 |
| Elbon | 3.0 | 3.0 | 3.0 | 3.0 | 2.0 | 90.3 | 1.8 ab | 2.5 | 3.0 | 3.0 | 2.0 ab | 95.0 |
| Maton | 2.8 | 3.0 | 3.0 | 3.0 | 2.5 | 85.5 | 2.0 ab | 2.5 | 3.0 | 3.0 | 1.3 b | 95.0 |
| Maton II | 2.8 | 3.0 | 3.0 | 3.0 | 1.8 | 85.5 | 1.0 b | 2.5 | 3.0 | 3.0 | 2.0 ab | 95.0 |
| Wintergrazer 70 | 3.0 | 3.0 | 3.0 | 3.0 | 2.3 | 90.3 | 2.8 ab | 2.8 | 3.0 | 3.0 | 1.5 ab | 95.0 |
| Wrens Abruzzi | 2.8 | 3.0 | 3.0 | 3.0 | 2.3 | 90.3 | 2.3 ab | 2.8 | 3.0 | 3.0 | 1.8 ab | 95.0 |
| Mean | 2.9 | 3.0 | 3.0 | 3.0 | 2.3 | 89.2 | 2.1 | 2.7 | 3.0 | 3.0 | 2.2 | 95.0 |
| Std. dev[#] | 0.3 | 0.0 | 0.0 | 0.0 | 0.6 | 8.9 | 1.0 | 0.5 | 0.0 | 0.0 | 1.1 | 0.0 |

| | 2016/2017 | | | | | | 2017/2018 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cultivar | Germination[¥] | | | | Disease Resistance[£] | Canopy Cover[§] | Germination[¥] | | | | Disease Resistance[£] | Canopy Cover[§] |
| Winter Cereal Rye | 7 DAP | 14 DAP | 21 DAP | 28 DAP | ——50% Anthesis—— | | 7 DAP | 14 DAP | 21 DAP | 28 DAP | ——50% Anthesis—— | |
| Brasetto | 2.8 | 2.8 | 2.8 | 2.8 | 2.0 | 71.3 | 1.5[¢] | 2.8 ab | 2.8 | 3.0[¢] | 1.8 ab | 95.0 |
| Guardian | 3.0 | 3.0 | 3.0 | 3.0 | 2.5 | 71.3 | 1.3 | 1.8 b | 2.3 | 2.3 | 2.0 ab | 95.0 |
| Hazlet | 3.0 | 3.0 | 3.0 | 3.0 | 3.3 | 76.0 | 2.5 | 3.0 a | 3.0 | 3.0 | 2.3 a | 95.0 |
| Oklon | 2.8 | 3.0 | 3.0 | 3.0 | 2.5 | 76.0 | 1.8 | 3.0 a | 3.0 | 3.0 | 1.0 b | 95.0 |
| Rymin | 3.0 | 3.0 | 3.0 | 3.0 | 2.8 | 76.0 | 2.5 | 3.0 a | 3.0 | 3.0 | 2.5 a | 95.0 |
| Wheeler | 2.8 | 3.0 | 3.0 | 3.0 | 2.8 | 85.5 | 1.3 | 2.3 ab | 2.8 | 2.8 | 1.8 ab | 95.0 |
| Mean | 2.9 | 3.0 | 3.0 | 3.0 | 2.6 | 76.0 | 1.8 | 2.6 | 2.8 | 2.8 | 1.9 | 95.0 |
| Std. dev[#] | 0.3 | 0.2 | 0.2 | 0.2 | 0.7 | 7.9 | 0.8 | 0.7 | 0.4 | 0.4 | 0.6 | 0.0 |

[#]Standard deviation

*Means in columns followed by the same letters are not significantly different at $P<0.05$.

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[ς]There were significant differences in ranks between cultivars according to Kruskal-Wallis one-way analysis of variance, but no separation of the ranks was achieved with Dunn's all pairwise comparison test.

¥Germination rated on the following scale: 0=poor (<25% germination), 1=moderate (30-60%), 2=good (65-85%), 3=excellent (90-100%).

[£]Disease/Insect Resistance rated on the following scale: 0=no damage, 1=slight damage, 3=moderate damage, 5=severe damage.

[§]Canopy Cover rated as a visual estimate of the percentage of ground covered by the seeded species.

DAP = days after planting.

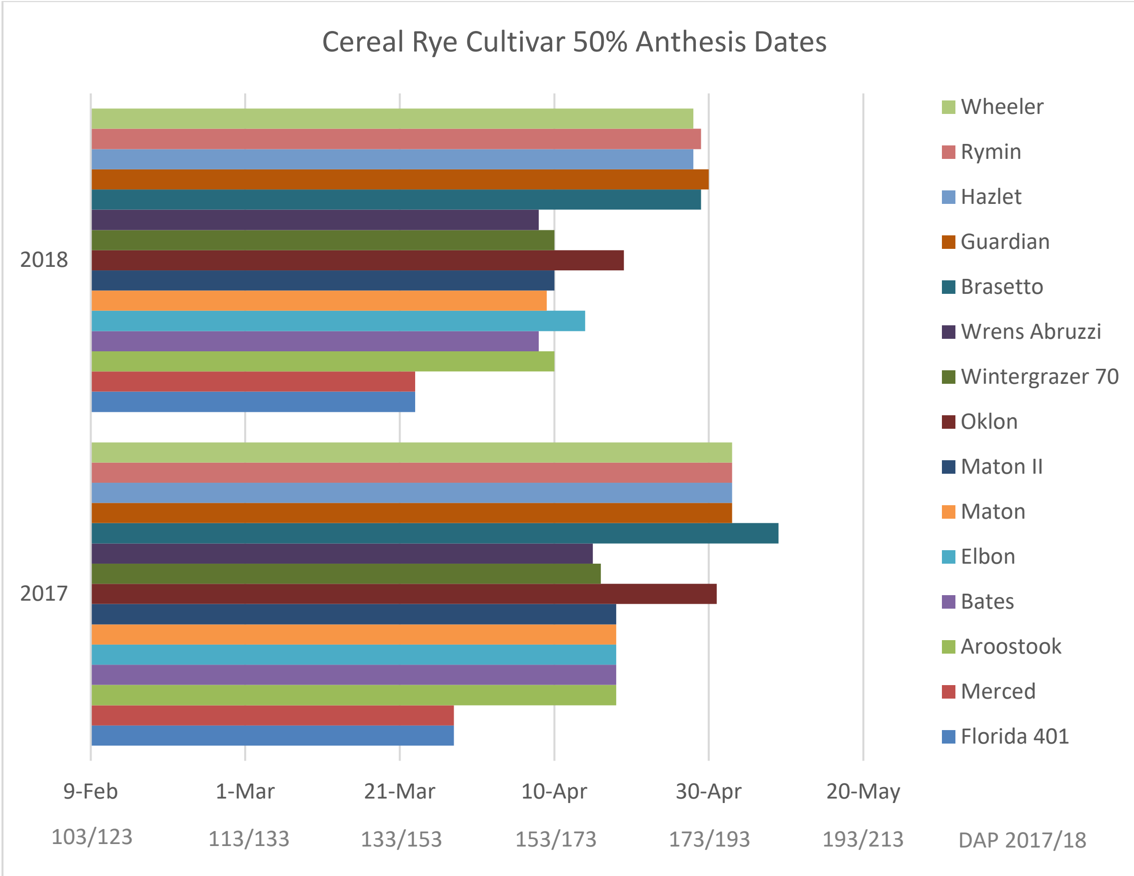


**Figure 10**. Differences between 50% anthesis dates of cereal rye cultivars across two growing seasons. DAP = Days after planting. Planting dates for 2017 were two weeks earlier than in 2016. Florida 401 and Merced were the first to bloom during late March of both years.

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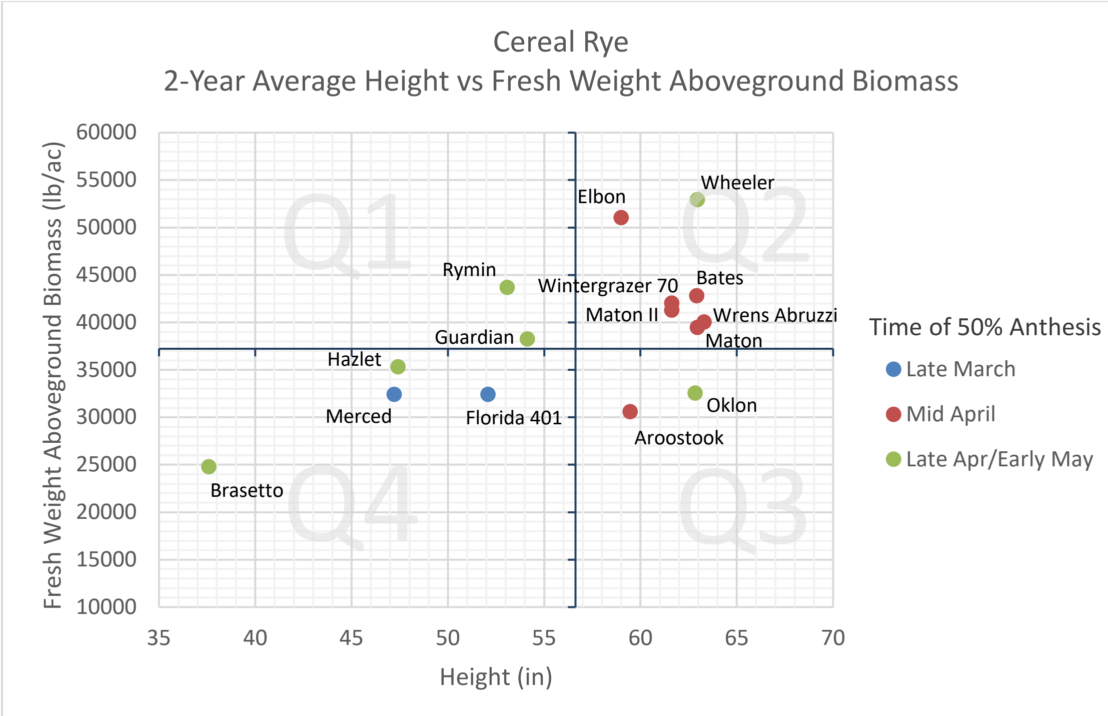


**Figure 11**. Differences shown between cereal rye cultivars across a two-year average of height versus fresh weight aboveground biomass (FWAB) at 50% anthesis. Axes represent the median height data (56.6 inches) and FWAB data over two years (37,229 lb/ac) and break the graph into four quadrants. In the resulting quadrants Q1 = shorter height, but high biomass, Q2 = tall with high biomass, Q3 = tall with low biomass, and Q4 = short and have low biomass. Bates, Elbon, Maton, Maton II, Wheeler, Wintergrazer 70, and Wrens Abruzzi were all tall with high FWAB.

**Table 14.** Crimson clover cultivar average quantitative measurements at 50% bloom including days after planting, height, and fresh weight aboveground biomass collected at the Lockeford Plant Materials Center, CA 2016/17 and 2017/18.

| | 2016/2017 | | | | 2017/2018 | | | |
|---|---|---|---|---|---|---|---|---|
| Cultivar | DAP | Height | | Fresh Weight Aboveground Biomass | DAP | Height | | Fresh Weight Aboveground Biomass |
| | | –in– | | ——lb/ac—— | | –in– | | ——lb/ac—— |
| AU Robin | 155 | 18.8 | a* | 31,211 | 176 | 21.7 | bc | 105,219 |
| AU Sunrise | 153 | 18.5 | a | 40,814 | 176 | 20.6 | bcd | 90,627 |
| AU Sunup | 148.5 | 17.5 | a | 16,806 | 167 | 22.2 | b | 45,616 |
| Contea | 161 | 20.5 | a | 26,409 | 180 | 15.8 | d | 86,880 |
| Dixie | 161 | 21.0 | a | 38,413 | 181 | 16.8 | cd | 91,541 |
| Kentucky Pride | 174 | 21.0 | a | 32,411 | 187 | 27.6 | a | 92,325 |
| Mean | 159 | 19.5 | | 31,011 | 178 | 20.80 | | 85,368 |
| Std. dev# | 9 | 2.2 | | 23,565 | 6 | 4.40 | | 44,160 |

#Standard deviation

*Means in columns followed by the same letters are not significantly different at *P*<0.05.

All measurements were collected at 50% bloom.

DAP = days after planting; in = inches; lb/ac = pounds/acre.

**Table 15.** Crimson clover cultivar average dry matter percent, total percent nitrogen, estimated dry matter yield and total nitrogen yield collected at the Lockeford Plant Materials Center, CA 2016/17 and 2017/18.

| | 2016/2017 | | | | 2017/2018 | | | |
|---|---|---|---|---|---|---|---|---|
| Cultivar | DM | Total N | Estimated DM Yield | Estimated Total N Yield | DM | Total N | Estimated DM Yield | Estimated Total N Yield |
| | ——%—— | | —lb/ac— | —lb/ac— | ——%—— | | —lb/ac— | —lb/ac— |
| AU Robin | 11.6 | 1.7 | 3,620 | 62 | 12.0 | 1.8 | 12,626 | 230 |
| AU Sunrise | 11.8 | 1.7 | 4,816 | 80 | 11.5 | 2.0 | 10,422 | 212 |
| AU Sunup | 11.0 | 1.9 | 1,849 | 35 | 11.9 | 2.5 | 5,428 | 136 |
| Contea | 15.1 | 1.5 | 3,988 | 58 | 13.4 | 1.9 | 11,642 | 222 |
| Dixie | 15.2 | 2.0 | 5,839 | 119 | 14.2 | 2.4 | 12,999 | 307 |
| Kentucky Pride | 19.2 | 2.2 | 6,223 | 137 | 13.2 | 3.1 | 12,187 | 379 |
| Mean | 14.0 | 1.80 | 4,428 | 83 | 12.7 | 2.3 | 10,879 | 248 |
| Std. dev# | 3.1 | 0.30 | 1,744 | 43 | 1.1 | 0.5 | 2,816 | 84 |

#Standard deviation

DM and N were measurements of composite samples collected at 50% bloom.

Est. DM Calculation: Fresh Weight Aboveground Biomass x (DM/100)

Est. Total N Yield Calculation: (Total N/100) x DM Yield

DM = dry matter, N = nitrogen, lb/ac = pounds/acre.

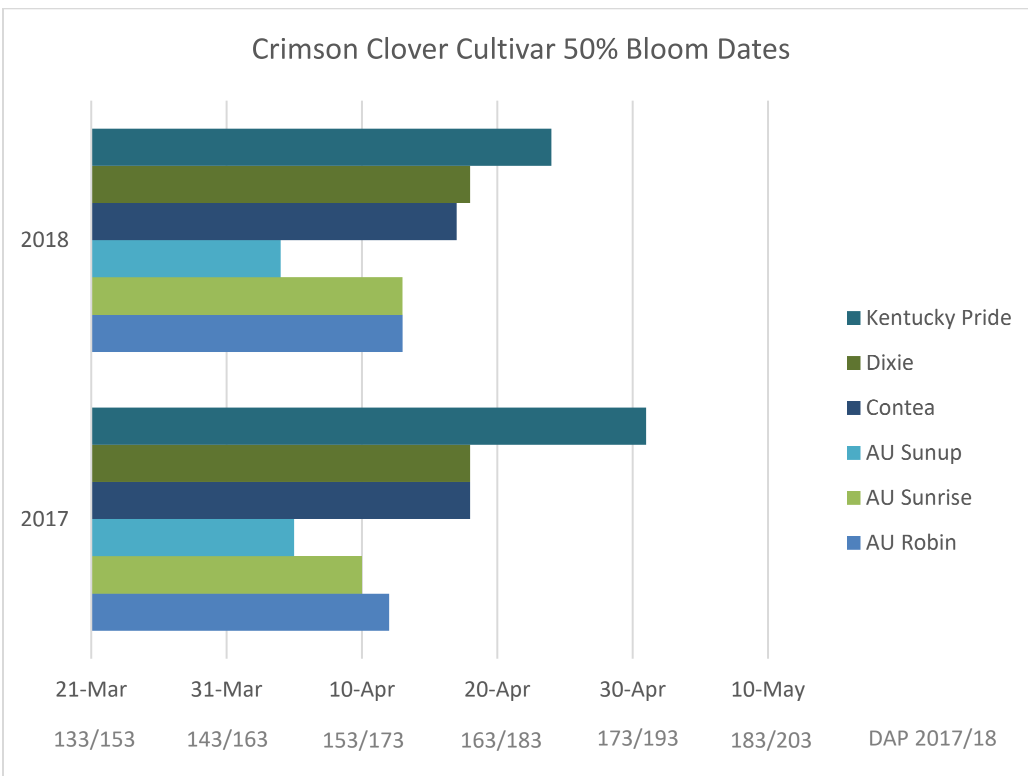


**Figure 12**. Differences between 50% bloom dates of crimson clover cultivars across two growing seasons. The 50% bloom date indicates maximum nitrogen content of the cover crop. DAP = Days after planting. Planting dates for 2017 were two weeks earlier than in 2016. During both years, AU Sunup was the first to bloom, while Kentucky Pride was last.

**Table 16.** Crimson clover cultivar average ordinal data including average germination at 7, 14, 21, and 28 days after planting, disease resistance and canopy cover at 50% bloom collected at the Lockeford Plant Materials Center, CA 2016/17 and 2017/18.

| | 2016/2017 | | | | | | 2017/2018 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cultivar | Germination[¥] | | | | Disease Resistance[£] | Canopy Cover[§] | Germination[¥] | | | | Disease Resistance[£] | Canopy Cover[§] |
| | 7 DAP | 14 DAP | 21 DAP | 28 DAP | ———50% Bloom——— | | 7 DAP | 14 DAP | 21 DAP | 28 DAP | ———50% Bloom——— | |
| AU Robin | 0.5 a* | 1.5 ab | 1.8 ab | 2.0 a | 1.0 a | 76.0 a | 0.0 a | 0.5 ab | 1.0 ab | 1.0 a | 0.0 b | 66.5 ab |
| AU Sunrise | 0.5 a | 2.0 a | 2.0 a | 2.0 a | 1.0 a | 80.8 a | 0.0 a | 1.3 a | 1.3 a | 1.5 a | 0.0 b | 76.0 a |
| AU Sunup | 0.3 a | 1.0 b | 1.0 b | 1.0 b | 1.0 a | 66.5 a | 0.0 a | 0.0 b | 0.5 b | 0.8 a | 1.0 ab | 47.5 b |
| Contea | 0.5 a | 1.8 ab | 1.8 ab | 1.8 ab | 1.0 a | 80.8 a | 0.0 a | 0.3 ab | 1.0 ab | 1.0 a | 1.5 a | 71.3 ab |
| Dixie | 0.5 a | 2.0 a | 2.0 a | 2.0 a | 1.0 a | 76.0 a | 0.0 a | 0.5 ab | 1.0 ab | 1.0 a | 1.5 a | 71.3 ab |
| Kentucky Pride | 0.5 a | 2.0 a | 2.0 a | 2.0 a | 1.0 a | 61.8 a | 0.0 a | 1.0 ab | 1.0 ab | 1.5 a | 1.0 ab | 71.3 ab |
| Mean | 0.5 | 1.7 | 1.8 | 1.8 | 1.0 | 73.6 | 0.0 | 0.6 | 1.0 | 1.1 | 0.8 | 67.3 |
| Std. dev[#] | 0.5 | 0.5 | 0.4 | 0.4 | 0.0 | 14.1 | 0.0 | 0.6 | 0.4 | 0.4 | 0.7 | 13.7 |

[#]Standard deviation

*Means in columns followed by the same letters are not significantly different at *P*<0.05.

[¢]There were significant differences in ranks between cultivars according to Kruskal-Wallis one-way analysis of variance, but no separation of the ranks was achieved with Dunn's all pairwise comparison test.

[¥]Germination rated on the following scale: 0=poor (<25% germination), 1=moderate (30-60%), 2=good (65-85%), 3=excellent (90-100%).

[£]Disease/Insect Resistance rated on the following scale: 0=no damage, 1=slight damage, 3=moderate damage, 5=severe damage.

[§]Canopy Cover rated as a visual estimate of the percentage of ground covered by the seeded species.

DAP = days after planting.

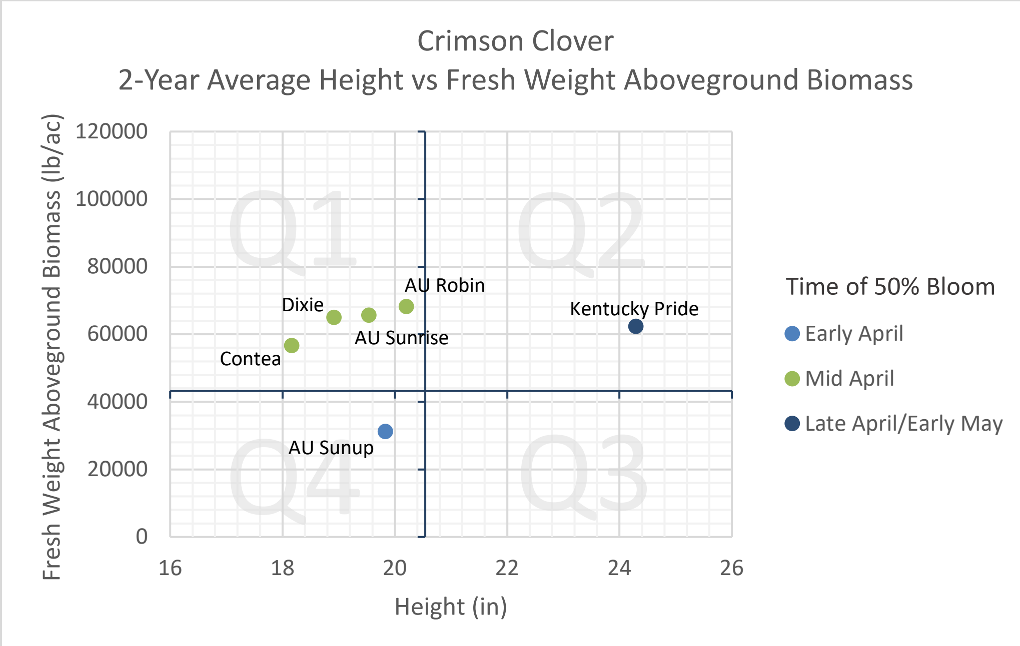


**Figure 13**. Differences shown between crimson clover cultivars across a two-year average of height versus fresh weight aboveground biomass (FWAB) at 50% bloom. Axes represent the median height data (20.5 inches) and FWAB data (43,215 lb/ac) and break the graph into four quadrants. In the resulting quadrants Q1 = shorter height, but high biomass, Q2 = tall with high biomass, Q3 = tall with low biomass, and Q4 = short and have low biomass. Kentucky Pride was tall, while AU Robin, AU Sunrise, Contea and Dixie also had FWAB above the median value.

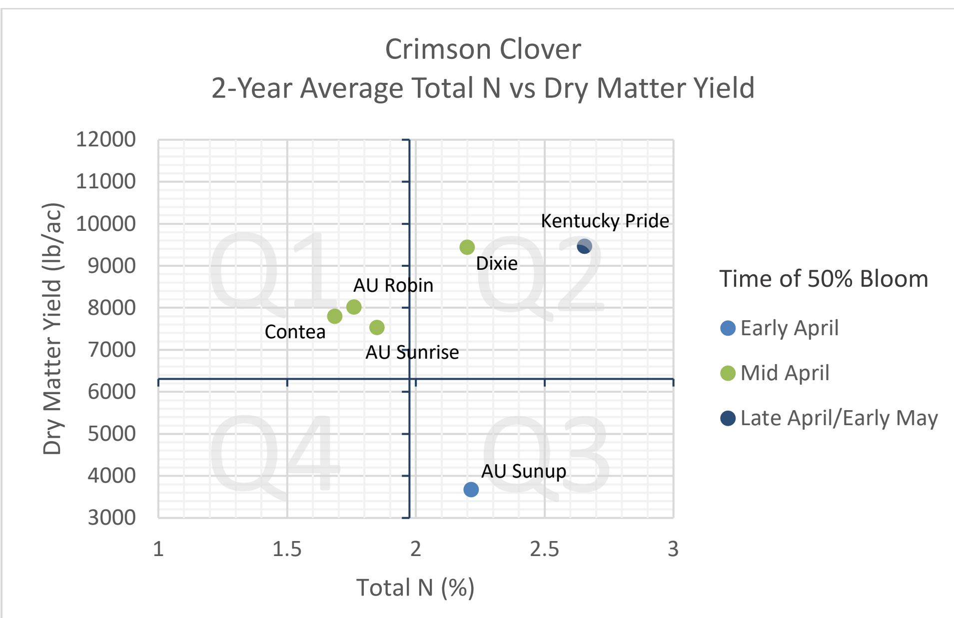


**Figure 14.** Differences shown in estimated total nitrogen (TN) yield between crimson clover cultivars across a two-year average of TN versus dry matter (DM) yield at 50% bloom. Axes represent the median TN data (2.0%) and DM yield data (6,308 lb/ac) and break the graph into four quadrants. In the resulting quadrants Q1 = high DM, but low TN, Q2 = high DM and high TN translating to high estimated TN yield, Q3 = low DM, but high TN, and Q4 = both low DM and low TN. Dixie and Kentucky Pride were both high in TN content and DM yield

**Table 17.** Daikon radish cultivar average quantitative measurements at 50% bloom including days after planting, height, and fresh weight aboveground biomass collected at the Lockeford Plant Materials Center, CA 2016/17 and 2017/18.

| | 2016/2017 | | | | 2017/2018 | | | |
|---|---|---|---|---|---|---|---|---|
| Cultivar | DAP | Height | | Fresh Weight Aboveground Biomass | DAP | Height | | Fresh Weight Aboveground Biomass |
| | | —in— | | –––lb/ac––– | | —in— | | –––lb/ac––– |
| Big Dog | 125 | 29.5 | cd | 85,230 | 141 | 25.1 | ab | 42,015 |
| Concorde | 140 | 40.8 | ab | 118,841 | 155 | 32.4 | ab | 70,825 |
| Control | 139 | 43.3 | a | 102,035 | 155 | 31.2 | ab | 48,017 |
| Defender | 132 | 30.0 | c | 51,618 | 154 | 32.6 | a | 63,622 |
| Driller | 120 | 21.0 | f | 28,810 | 141 | 25.2 | ab | 39,614 |
| Eco-till | 125 | 30.5 | c | 70,825 | 141 | 25.8 | ab | 42,015 |
| Graza | 148 | 37.0 | b | 78,027 | 173 | 32.9 | a | 17,794 |
| Groundhog | 122 | 27.0 | cde | 52,818 | 141 | 27.4 | ab | 50,417 |
| Lunch | 119 | 22.7 | ef | 27,610 | 141 | 25.6 | ab | 37,213 |
| Nitro | 122 | 28.5 | cd | 75,626 | 141 | 26.9 | ab | 61,221 |
| Sodbuster Blend | 125 | 31.0 | c | 52,818 | 141 | 26.1 | ab | 39,614 |
| Tilllage | 120 | 24.0 | def | 38,413 | 141 | 24.3 | b | 39,614 |
| Mean | 128 | 30.6 | | 65,223 | 147 | 28.0 | | 45,998 |
| Std. dev# | 9 | 7.3 | | 45,454 | 10 | 5.1 | | 27,728 |

#Standard deviation

*Means in columns followed by the same letters are not significantly different at $P<0.05$.

All measurements were collected at 50% bloom.

DAP = days after planting; in = inches; lb/ac = pounds/acre.

**Table 18.** Daikon radish cultivar average dry matter percent, total percent nitrogen, estimated dry matter yield and total nitrogen yield collected at the Lockeford Plant Materials Center, CA 2016/17 and 2017/18.

| | 2016/2017 | | | | 2017/2018 | | | |
|---|---|---|---|---|---|---|---|---|
| Cultivar | DM | Total N | Estimated DM Yield | Estimated Total N Yield | DM | Total N | Estimated DM Yield | Estimated Total N Yield |
| | ——%—— | | —lb/ac— | —lb/ac— | ——%—— | | —lb/ac— | —lb/ac— |
| Big Dog | 8.8 | 3.2 | 7,500 | 238 | 10.6 | 2.1 | 4,454 | 93 |
| Concorde | 10.2 | 3.1 | 12,122 | 373 | 11.0 | 2.2 | 7,791 | 169 |
| Control | 9.8 | 3.2 | 9,999 | 317 | 10.8 | 2.1 | 5,186 | 106 |
| Defender | 10.3 | 3.5 | 5,317 | 184 | 10.1 | 2.7 | 6,426 | 175 |
| Driller | 12.1 | 2.9 | 3,486 | 101 | 9.7 | 2.2 | 3,843 | 83 |
| Eco-till | 9.4 | 3.6 | 6,658 | 240 | 11.3 | 2.4 | 4,748 | 115 |
| Graza | 11.4 | 3.5 | 8,895 | 312 | 16.4 | 1.5 | 2,918 | 43 |
| Groundhog | 11.4 | 2.6 | 6,021 | 154 | 10.5 | 2.3 | 5,294 | 123 |
| Lunch | 11.6 | 3.1 | 3,203 | 99 | 11.2 | 2.2 | 4,168 | 92 |
| Nitro | 10.0 | 3.2 | 7,563 | 239 | 10.1 | 2.4 | 6,183 | 151 |
| Sodbuster Blend | 8.7 | 3.2 | 4,595 | 146 | 11.4 | 1.9 | 4,516 | 87 |
| Tilllage | 10.7 | 1.6 | 4,110 | 65 | 10.0 | 2.2 | 3,961 | 87 |
| Mean | 10.4 | 3.0 | 6,628 | 206 | 11.1 | 2.2 | 4,957 | 110 |
| Std. dev# | 1.1 | 0.5 | 2,855 | 99 | 1.8 | 0.3 | 1,332 | 39 |

#Standard deviation

DM and N were measurements of composite samples collected at 50% bloom.

Est. DM Calculation: Fresh Weight Aboveground Biomass x (DM/100)

Est. Total N Yield Calculation: (Total N/100) x DM Yield

DM = dry matter, N = nitrogen, lb/ac = pounds/acre.

**Table 19.** Daikon radish cultivar average ordinal data including average germination at 7, 14, 21, and 28 days after planting, insect resistance and canopy cover at 50% bloom collected at the Lockeford Plant Materials Center, CA 2016/17 and 2017/18.

| | 2016/2017 | | | | | | | | | 2017/2018 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cultivar | Germination[¥] | | | | | | | Insect Resistance[£] | Canopy Cover[§] | Germination[¥] | | | | | | | Insect Resistance[£] | | Canopy Cover[§] |
| | 7 DAP | | 14 DAP | 21 DAP | | 28 DAP | | ———50% Bloom——— | | 7 DAP | 14 DAP | | 21 DAP | | 28 DAP | | ———50% Bloom——— | | |
| Big Dog | 0.3 | a* | 2.0[¢] | 2.0 | a | 2.0 | a | 1.0[¢] | 76.0[¢] | 1.0[¢] | 2.8 | a | 3.0 | a | 3.0 | a | 1.0 | ab | 85.5 |
| Concorde | 0.8 | a | 2.0 | 2.0 | a | 2.0 | a | 1.8 | 80.8 | 1.0 | 2.5 | a | 3.0 | a | 3.0 | a | 2.0 | a | 80.8 |
| Control | 0.8 | a | 2.0 | 2.0 | a | 2.0 | a | 1.5 | 76.0 | 0.5 | 2.3 | a | 2.5 | ab | 2.5 | ab | 2.0 | a | 71.3 |
| Defender | 0.0 | a | 1.5 | 1.5 | ab | 1.5 | ab | 1.8 | 42.8 | 0.5 | 2.5 | a | 2.8 | ab | 2.8 | ab | 2.0 | a | 76.0 |
| Driller | 1.0 | a | 2.0 | 2.0 | a | 2.0 | a | 1.0 | 57.0 | 0.8 | 2.5 | a | 2.8 | ab | 2.8 | ab | 1.0 | ab | 80.8 |
| Eco-till | 0.8 | a | 2.0 | 2.0 | a | 2.0 | a | 1.0 | 66.5 | 1.3 | 2.8 | a | 3.0 | a | 3.0 | a | 1.0 | ab | 80.8 |
| Graza | 0.3 | a | 1.0 | 1.0 | b | 1.0 | b | 1.3 | 38.0 | 0.0 | 1.3 | a | 1.5 | b | 1.5 | b | 1.5 | ab | 38.0 |
| Groundhog | 0.8 | a | 2.0 | 2.0 | a | 2.0 | a | 1.0 | 66.5 | 1.0 | 2.5 | a | 3.0 | a | 3.0 | a | 1.3 | ab | 85.5 |
| Lunch | 0.3 | a | 1.8 | 1.8 | ab | 1.8 | ab | 1.0 | 52.3 | 0.5 | 2.5 | a | 3.0 | a | 3.0 | a | 0.8 | b | 85.5 |
| Nitro | 0.8 | a | 2.0 | 2.0 | a | 2.0 | a | 1.0 | 71.3 | 0.5 | 2.3 | a | 2.5 | ab | 2.8 | ab | 1.0 | ab | 76.0 |
| Sodbuster Blend | 0.8 | a | 1.3 | 1.8 | ab | 1.8 | ab | 1.0 | 66.5 | 0.3 | 2.8 | a | 2.8 | ab | 2.8 | ab | 1.0 | ab | 80.8 |
| Tilllage | 0.5 | a | 1.8 | 2.0 | a | 2.0 | a | 1.0 | 66.5 | 0.3 | 2.8 | a | 2.8 | ab | 2.8 | ab | 1.0 | ab | 80.8 |
| Mean | 0.6 | | 1.8 | 1.8 | | 1.8 | | 1.2 | 63.3 | 0.6 | 2.4 | | 2.7 | | 2.7 | | 1.3 | | 76.8 |
| Std. dev[#] | 0.5 | | 0.4 | 0.4 | | 0.4 | | 0.4 | 18.1 | 0.5 | 0.7 | | 0.5 | | 0.5 | | 0.5 | | 16.1 |

[#]Standard deviation

*Means in columns followed by the same letters are not significantly different at *P*<0.05.

[¢]There were significant differences in ranks between cultivars according to Kruskal-Wallis one-way analysis of variance, but no separation of the ranks was achieved with Dunn's all pairwise comparison test.

[¥]Germination rated on the following scale: 0=poor (<25% germination), 1=moderate (30-60%), 2=good (65-85%), 3=excellent (90-100%).

[£]Disease/Insect Resistance rated on the following scale: 0=no damage, 1=slight damage, 3=moderate damage, 5=severe damage.

[§]Canopy Cover rated as a visual estimate of the percentage of ground covered by the seeded species.

DAP = days after planting.

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

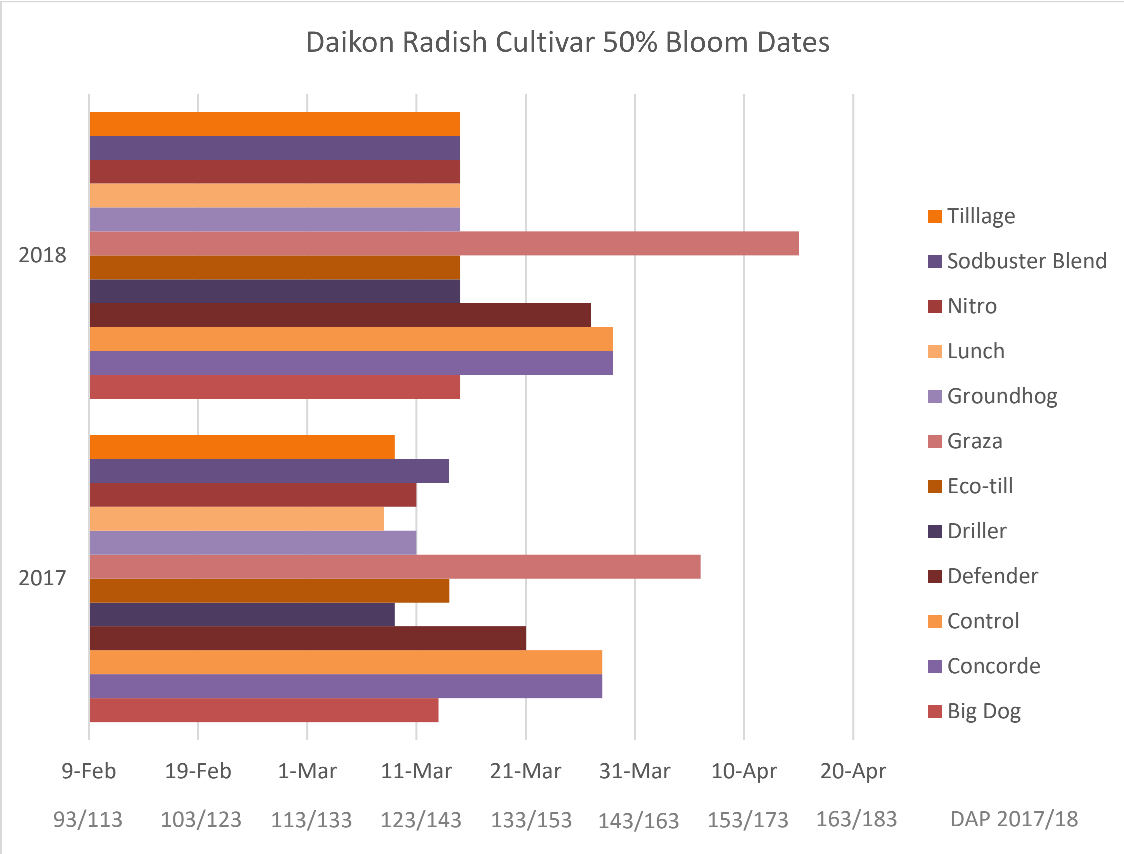


**Figure 15**. Differences between 50% bloom dates of daikon radish cultivars across two growing seasons. The 50% bloom date indicates maximum nitrogen content of the cover crop. DAP = Days after planting. Planting dates for 2017 were two weeks earlier than in 2016. Graza was the last to bloom during both years.

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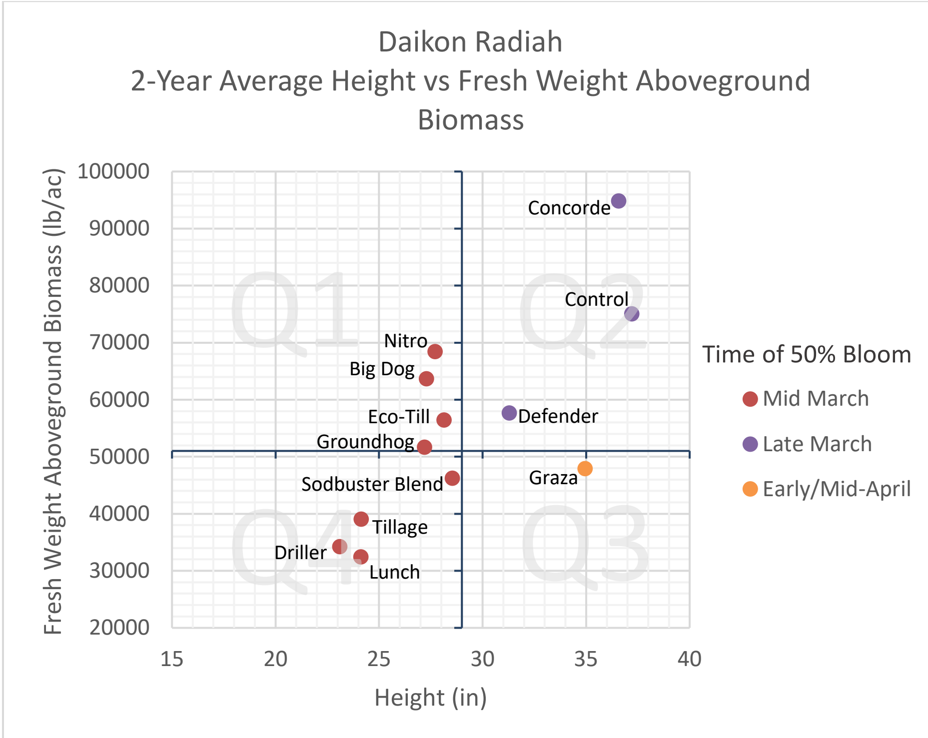


**Figure 16**. Differences shown between daikon radish cultivars across a two-year average of height versus fresh weight aboveground biomass (FWAB) at 50% bloom. Axes represent the median of daikon radish height data (29 inches) and FWAB data (51,018 lb/ac) and break the graph into four quadrants. In the resulting quadrants Q1 = shorter height, but high biomass, Q2 = tall with high biomass, Q3 = tall with low biomass, and Q4 = short and have low biomass. Concorde, Control, and Defender were both tall and had high FWAB.

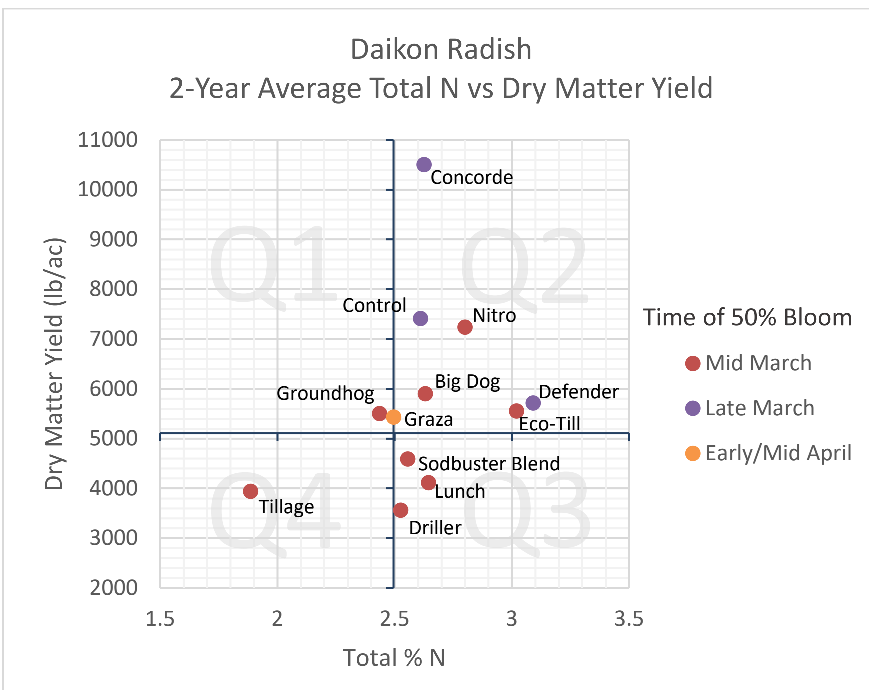


**Figure 17.** Differences shown in estimated total nitrogen (TN) yield between daikon radish cultivars across a two-year average of TN versus dry matter (DM) yield at 50% bloom. Axes represent the median of daikon radish TN data (2.5%) and DM yield data (5,108 lb/ac) and break the graph into four quadrants. In the resulting quadrants Q1 = high DM, but low TN, Q2 = high DM and high TN translating to high estimated TN yield, Q3 = low DM, but high TN, and Q4 = both low DM and low TN. Big Dog, Concorde, Control, Defender, Eco-Till, and Nitro had both high TN content and DM yield.

**Table 20.** Hairy vetch cultivar average quantitative measurements at 50% bloom including days after planting, height, and fresh weight aboveground biomass collected at the Lockeford Plant Materials Center, CA 2016/17 and 2017/18.

| | 2016/17 | | | | 2017/18 | | | |
|---|---|---|---|---|---|---|---|---|
| Cultivar | DAP | Height | | Fresh Weight Aboveground Biomass | DAP | Height | | Fresh Weight Aboveground Biomass |
| | | —in— | | ———lb/ac——— | | —in— | | ———lb/ac——— |
| CCS-Groff | 187 | 26.75 | a | 31,211 | 202 | 31.4 | abc | 47,241 |
| Lana | 176 | 21.25 | a | 40,814 | 187 | 29.3 | abc | 42,558 |
| Purple Bounty | 187 | 26.25 | a | 32,411 | 200 | 32.9 | ab | 43,212 |
| Purple Prosperity | 182 | 22.25 | a | 37,213 | 199 | 34.1 | a | 61,398 |
| TNT | 187 | 26.75 | a | 42,015 | 206 | 27.2 | c | 51,902 |
| Villana | 187 | 27.25 | a | 33,612 | 207 | 28.2 | bc | 52,773 |
| Mean | 184 | 25.1 | | 36,213 | 200 | 30.5 | | 49,847 |
| Std. dev# | 5 | 3.6 | | 9,601 | 7 | 3.2 | | 13,317 |

#Standard deviation

*Means in columns followed by the same letters are not significantly different at $P<0.05$.

All measurements were collected at 50% bloom.

DAP = days after planting; in = inches; lb/ac = pounds/acre.

**Table 21.** Hairy vetch cultivar average dry matter percent, total percent nitrogen, estimated dry matter yield and total nitrogen yield collected at the Lockeford Plant Materials Center, CA 2016/17 and 2017/18.

| | 2016/17 | | | | 2017/18 | | | |
|---|---|---|---|---|---|---|---|---|
| Cultivar | DM | Total N | Estimated DM Yield | Estimated Total N Yield | DM | Total N | Estimated DM Yield | Estimated Total N Yield |
| | ———%——— | | ——lb/ac—— | ——lb/ac—— | ———%——— | | ——lb/ac—— | ——lb/ac—— |
| CCS-Groff | 22.6 | 3.0 | 7,038 | 208 | 19.4 | 3.4 | 9,165 | 309 |
| Lana | 17.4 | 4.3 | 7,118 | 305 | 17.7 | 3.7 | 7,533 | 275 |
| Purple Bounty | 17.0 | 3.3 | 5,513 | 182 | 20.3 | 3.6 | 8,772 | 318 |
| Purple Prosperity | 21.4 | 2.8 | 7,975 | 222 | 19.0 | 2.8 | 11,666 | 330 |
| TNT | 18.0 | 3.6 | 7,567 | 269 | 20.3 | 3.6 | 10,536 | 381 |
| Villana | 19.6 | 3.0 | 6,598 | 198 | 19.4 | 3.6 | 10,238 | 373 |
| Mean | 19.3 | 3.3 | 6,901 | 231 | 19.4 | 3.5 | 9,756 | 335 |
| Std. dev# | 2.3 | 0.6 | 773 | 47 | 1.0 | 0.3 | 1,444 | 39 |

#Standard deviation

DM and N were measurements of composite samples collected at 50% bloom.

Est. DM Calculation: Fresh Weight Aboveground Biomass x (DM/100)

Est. Total N Yield Calculation: (Total N/100) x DM Yield

DM = dry matter, N = nitrogen, lb/ac = pounds/acre.

**Table 22.** Hairy vetch cultivar average ordinal data including average germination at 7, 14, 21, and 28 days after planting, disease resistance and canopy cover at 50% bloom collected at the Lockeford Plant Materials Center, CA 2016/17 and 2017/18.

| | 2016/2017 | | | | | | 2017/2018 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cultivar | Germination[¥] | | | | Disease Resistance[£] | Canopy Cover[§] | Germination[¥] | | | | Disease Resistance[£] | Canopy Cover[§] |
| | 7 DAP | 14 DAP | 21 DAP | 28 DAP | ——50% Bloom—— | | 7 DAP | 14 DAP | 21 DAP | 28 DAP | ———50% Bloom——— | |
| CCS-Groff | 0.3 | 1.3 | 1.8 | 2.0 | 2.0 | 90.3 | 0.0 | 0.8 | 2.0 | 2.0 | 1.3[¢] | 90.3 |
| Lana | 0.5 | 1.3 | 1.8 | 1.8 | 3.0 | 85.5 | 0.0 | 1.0 | 2.5 | 2.5 | 2.0 | 95.0 |
| Purple Bounty | 0.3 | 1.3 | 2.0 | 2.0 | 2.0 | 90.3 | 0.0 | 1.0 | 2.0 | 2.0 | 1.0 | 95.0 |
| Purple Prosperity | 0.5 | 1.5 | 2.0 | 2.0 | 2.0 | 95.0 | 0.0 | 1.0 | 1.8 | 1.8 | 1.3 | 90.3 |
| TNT | 0.8 | 1.8 | 1.8 | 1.8 | 2.0 | 95.0 | 0.0 | 1.5 | 2.0 | 2.0 | 1.3 | 90.3 |
| Villana | 0.5 | 1.8 | 2.0 | 2.0 | 2.0 | 95.0 | 0.0 | 1.5 | 2.3 | 2.3 | 1.8 | 85.5 |
| Mean | 0.5 | 1.5 | 1.9 | 1.9 | 2.2 | 91.8 | 0.0 | 1.1 | 2.1 | 2.1 | 1.4 | 91.0 |
| Std. dev[#] | 0.5 | 0.5 | 0.3 | 0.4 | 0.4 | 7.2 | 0.0 | 0.5 | 0.4 | 0.4 | 0.5 | 7.9 |

[#]Standard deviation

*Means in columns followed by the same letters are not significantly different at *P*<0.05.

[¢]There were significant differences in ranks between cultivars according to Kruskal-Wallis one-way analysis of variance, but no separation of the ranks was achieved with Dunn's all pairwise comparison test.

[¥]Germination rated on the following scale: 0=poor (<25% germination), 1=moderate (30-60%), 2=good (65-85%), 3=excellent (90-100%).

[£]Disease/Insect Resistance rated on the following scale: 0=no damage, 1=slight damage, 3=moderate damage, 5=severe damage.

[§]Canopy Cover rated as a visual estimate of the percentage of ground covered by the seeded species.

DAP = days after planting.

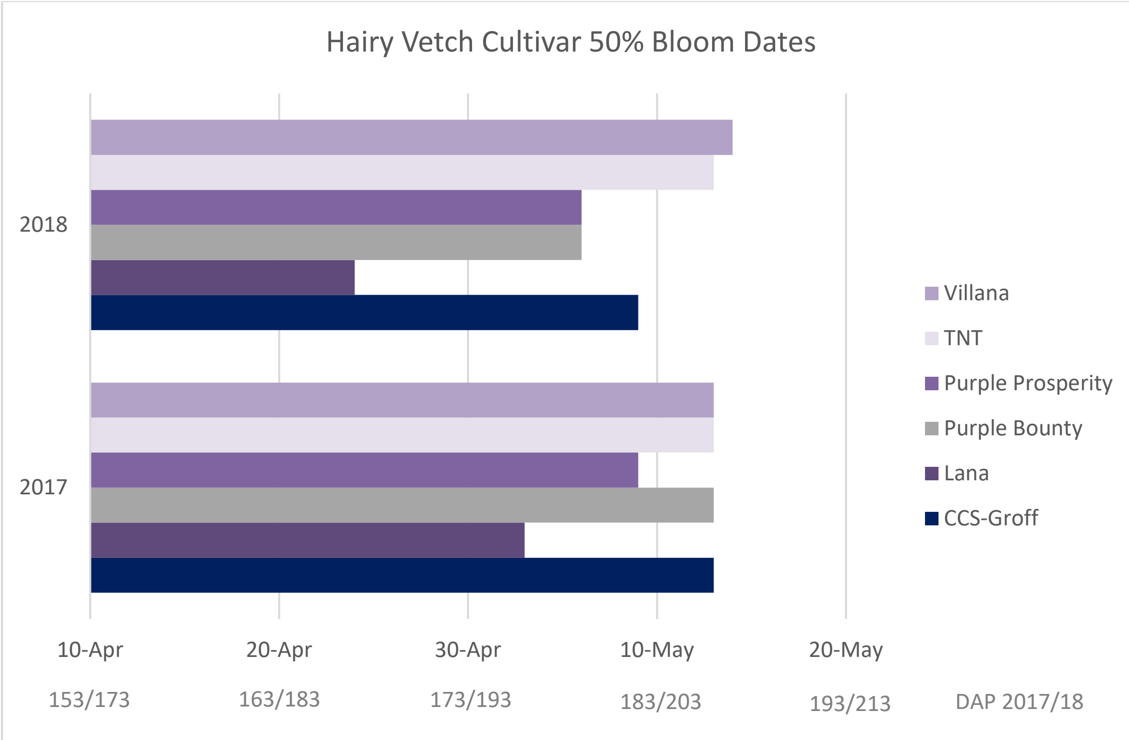


**Figure 18**. Differences between 50% bloom dates of hairy vetch cultivars across two growing seasons. The 50% bloom date indicates maximum nitrogen content of the cover crop. DAP = Days after planting. Planting dates for 2017 were two weeks earlier than in 2016. Lana was the first to bloom during both years.

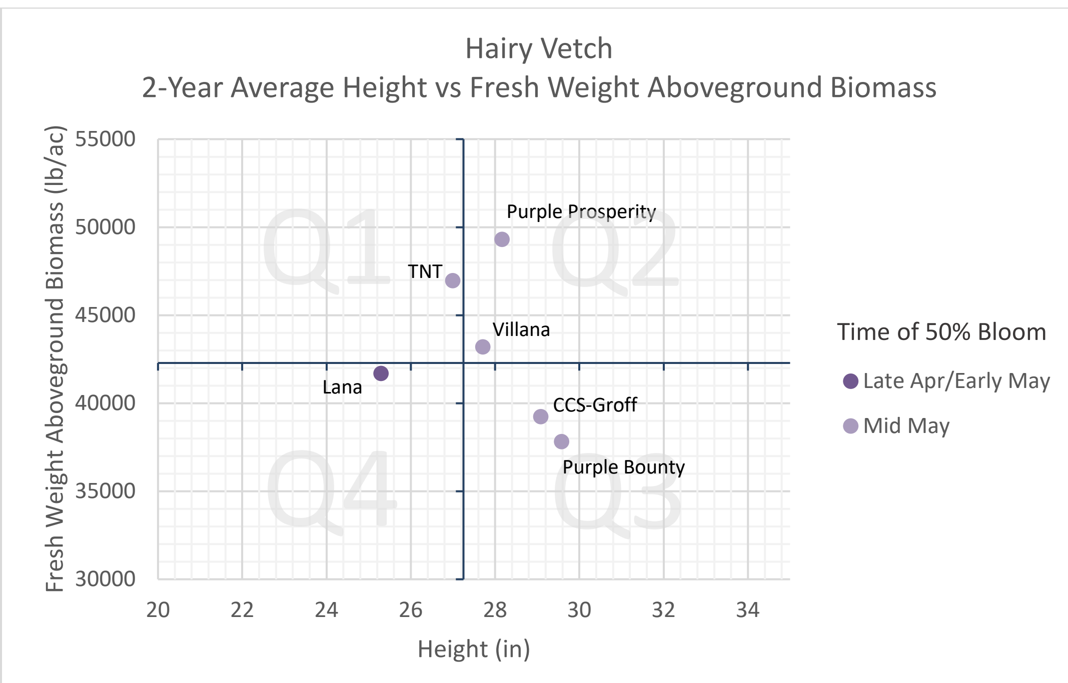


**Figure 19**. Differences shown between hairy vetch cultivars across a two-year average of height versus fresh weight aboveground biomass (FWAB) at 50% bloom. Axes represent the median height data (27.3 inches) and FWAB data (42,287 lb/ac) and break the graph into four quadrants. In the resulting quadrants Q1 = shorter height, but high biomass, Q2 = tall with high biomass, Q3 = tall with low biomass, and Q4 = short and have low biomass. Purple Prosperity and Villana were both tall and had the highest FWAB across hairy vetch cultivars.

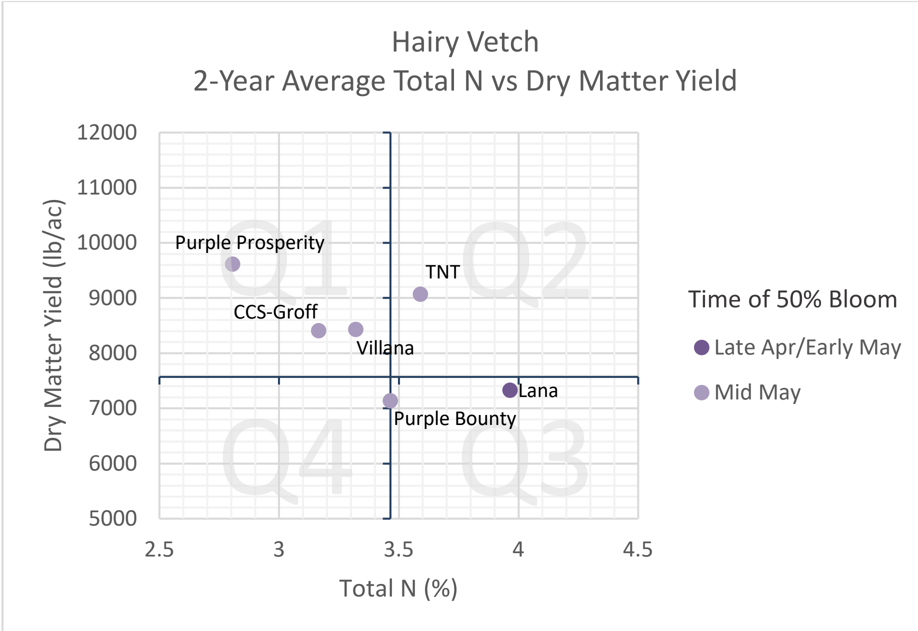


**Figure 20.** Differences shown in estimated total nitrogen (TN) yield between hairy vetch cultivars across a two-year average of TN versus dry matter (DM) yield at 50% bloom. Axes represent the median TN data (3.5%) and DM yield data (7,570 lb/ac) and break the graph into four quadrants. In the resulting quadrants Q1 = high DM, but low TN, Q2 = high DM and high TN translating to high estimated TN yield, Q3 = low DM, but high TN, and Q4 = both low DM and low TN. TNT was high in both TN content and DM yield.