Winter Legumes to Increase Water-Use-Efficiency in No-Till Systems?

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Our Story

In 1998 and 2000, Mike Greytak, a highly diversified no-till farmer in southeastern Montana, organized well attended no-till conferences in Billings. Much discussion at these farm conferences centered around stubble management questions for soil water management. Mike challenged us to develop a project that studied crop water-use-efficiency (WUE) in continuous, diversified dryland cropping systems in Montana. Our belief was that knowledge about maximizing WUE would lead to increased sustainability of Montana farming systems by increasing profitability and building healthier soils and biological diversity.

Western SARE seemed a logical source of funding for this type of sustainable agriculture research. We first applied for a research grant in 2000, and after our 3rd application in 2002, we were awarded 20% of our request. That was insufficient funding to conduct our planned project but we'd since become very interested in the potential for winter lentil and pea to help intensify winter wheat-based systems, and together with funding from the USDA Cool Season Food Legume program we planned a project to investigate the effects of wheat stubble management on winter survival, yield, and water use of winter lentil and pea. In 2001, Mike Greytak harvested two field plots of Austrian winter pea on his farm. His September seeding date yielded 22 bu/ac while a March seeding date yielded only 7 bu/ac. We were quite excited about the potential for winter legumes to be a "game changer" in diversifying fallow – winter wheat systems in a water-use-efficient manner.

Questions

1) How do winter lentil and winter pea compare for winterhardiness and are there genetic differences within pea or lentil for winterhardiness?
2) How do winter lentil and winter pea seed yield and WUE compare with spring lentil and pea?
3) How would cereal stubble height affect winter survival, and subsequent yield formation?
4) How early would winter lentil and pea have to be seeded to reduce the risk of overwinter stand loss?
5) Would optimal plant densities for winter lentil and pea be the same as their familiar spring counterparts?

Field Site

A field site was chosen at Amsterdam, MT, to represent the cold dry winter climate typical of the Rocky Mountain Front region. Long-term average annual precipitation is 14.1 inches (360 mm). This area grows winter wheat predominantly in a fallow – wheat cropping sequence.

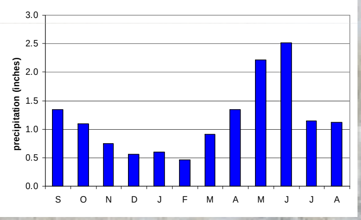


Figure 1. 1971-2000 average monthly precipitation, September to August, at Amsterdam, MT (annual total = 14.1 inches or 360 mm).

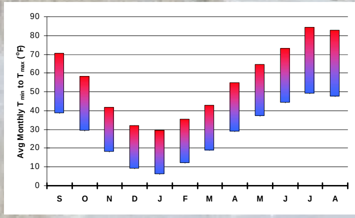


Figure 2. 1971-2000 average monthly minimum and maximum temperatures, September-August, at Amsterdam, MT.

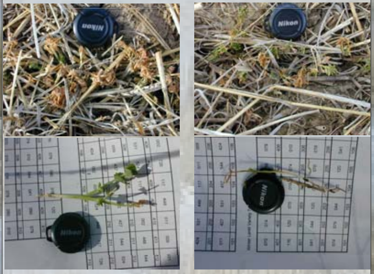
Experimental Parameters

Adjacent pea and lentil sites were established on representative no-till farm fields for 3 years. After wheat harvest, stubble was cut short (4 inches) or left tall (12 – 16 inches) for main plot treatments within each crop; pea and lentil. Early and late September seeding dates X two winter genotypes plus two high-yield spring cultivars were randomized as six subplots within the stubble height main plots. Experimental winter pulse breeding lines were referred to as *Morton* and '79' for lentil, and '706'(tall) and '726'(short) for pea. The controls were spring cultivars; *Brewer* and *Richlea* lentil, and *Delta* and *Mozart* pea. Plots were 6 x 40 ft. Additionally, one breeding line each of winter pea ('726') and lentil ('79') was seeded at four plant densities in early September in tall stubble only. Data collection included phenological development rates, stand density, grain productivity and quality, and soil water extraction.

Answers

1) Lentil vs. Pea Winterhardiness?

➢Pea has consistently shown greater winter survival in this and other studies at this location, possibly due to larger seed size tolerant of deeper seeding. In Rocky Mountain foothill environments it is very likely that the top growth of fall-emerged winter lentil and pea will be frozen off during snow-free periods in the winter, or during cold periods following spring snow melt. Pea and lentil must then re-emerge from below ground nodes. Frozen tissue damage may extend below the soil surface depending on the intensity and duration of the cold period, and shallower seeded lentils will suffer proportionally greater tissue damage.



Pea on left, lentil on right. Note tissue damage (upper photos) from 5°F on April 1, 2002, and greater ability of pea seedling to regenerate shoots from below-ground nodes.

➢Genetic variation for winterhardiness has been observed within both pea and lentil within this and related studies. Maximum winterhardiness in pea comes from pigmented Austrian winter types that were not present in this study. In this study, breeding line '79' showed greater survival than *Morton* red lentil at Amsterdam, but not at other locations in a related study. Within Montana, variety evaluation for pea and lentil winterhardiness continues at Amsterdam and Moccasin, in support of the winter legume breeding program at USDA-ARS Pullman, WA.

2) Winter vs. Spring?

➢Winter lentil and pea flowered 10 and 7 days earlier than early-seeded spring counterparts. Lentil matured 6 days earlier than spring counterparts but pea matured 4 days later than spring counterparts, indicating genetic improvement needed for the rate of seed fill in winter pea.

➢Winter pea and lentil yielded equal or lower than high yielding modern spring cultivars in 2002 and 2003 at Amsterdam; in 2004, persistent dry fall soil conditions resulted in no fall establishment and complete stand failure for all winter lentil and winter pea treatments, highlighting need for moist soil conditions in September. In related research in central Montana winter lentil yielded equal or greater than spring lentil, by as much as 70% (Chen et al., 2006). Limited farmer experience in Montana has since shown increased yield potential with *Morton* winter lentil.

➢Winter pea has consistently shown faster biomass accumulation within the growing season highlighting potential for high quality forage production, or as a green manure (Miller et al., 2008). Biological N fixation has begun sooner in the season, resulting in greater N fixation by a given calendar date or when the season is terminated by early summer drought. However, the depth of soil water extraction did not differ between winter and spring types of pea or lentil, with no water use observed below 3 ft.

Spring pea roots on left, winter pea roots on the right, May 31, 2002. Note superior root formation and nodulation on the winter lentil.

3) Stubble height effects?

➢Tall stubble was reported to increase WUE in spring pea and lentil (Cutforth et al., 2002).

➢Stubble height effects on winter pea and lentil were inconsistent in this study. In fall 2001, rain during Sep 9 - 21, followed by warm growing conditions, resulted in superior establishment in tall stubble. Further, snowpack remained in tall stubble, but not in short stubble, during a 5°F overnight freeze April 1, 2002. This protected seedlings during a critical injury event, resulting in a clear survival/yield advantage in tall stubble. In fall 2002, precipitation was delayed until Oct 11, followed by cool growing conditions. Establishment, survival, and yield was superior in the warmer short stubble micro-environment. In fall 2003, September precipitation was insufficient to germinate pea and lentil, and no precipitation was received in Oct or Nov, resulting in zero survival for all winter pea and lentil plots. The farmer's spring pea field yielded 30% greater in the tall stubble plots.

➢In a related study in central Montana, with lighter stubble conditions associated with much lower wheat yield potential, stubble height increased winter lentil yield consistently by 2.5 bu/ac, but not winter pea (Chen et al., 2006). Yield increase in winter lentil was associated with increased WUE and improved harvestability due to 1-inch taller plants. In subsequent observations, winter pea and lentil establishment and survival was optimized under light cereal residue conditions consistent with wheat yields of 30 bu/ac or less, or higher yields with straw removal.

Winter lentil in tall vs short stubble, June 16, 2003, Amsterdam, MT.

4) Fall seeding date?

- Recommendations from this and subsequent studies in Montana are that winter pea and lentil should be seeded earlier than winter wheat, ideally into moist soil prior to Sep 14.
- Farmer experience with seeding date has been inconsistent. Farmer seeding date trials at Big Sandy, MT, (Bob Quinn) showed superior plant density and spring growth associated with Sep 17 compared with Sep 30 seeding dates, but acceptable stands in both cases. However, another grower in SE Montana near Baker, MT, reported good success with dormant fall planting in late October to early November for two years. Another grower in SW Montana had no success with dormant seeding

Exp Line '79' winter lentil seeded Sep 13 (left) and Sep 30 (right). Photos June 16, 2003, Amsterdam, MT.

5) Optimal Seeding Rates?

- Seeding rates targeted 40, 80 (=1X), 120, and 160 plants/m² for pea and 60, 120 (=1X), 180, and 240 plants/m² for lentil. Results from this and related studies suggested farmers should increase seeding rates by 25 - 50% over that used for spring types since fall germination was less successful than spring germination (fall averaged 75% of spring rate) and some degree of overwinter stand loss is unavoidable.
- An important complication is that winter pea and lentil stand loss is typically 'patchy,' resulting in **special weed management challenges**. In fact, following winter survival, weed management is likely the leading challenge that farmers face with winter pea and lentil production.

Winter lentil in tall stubble at Amsterdam, MT, June 16, 2003. Seeding date = Sep 13, variety = Exp Line '79'. (best case winter lentil)

Spring lentil in tall stubble at Amsterdam, MT, June 16, 2003. Seeding date = Apr 9, variety = Richlea.

➢ Citations

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