

Re-inventing Austrian winter pea

Towards developing food quality winter peas

In the dry areas of the Pacific Northwest where the typical rotation is winter wheat–summer fallow, farmers need a broadleaf rotational crop to improve the sustainability of the cropping system. Fall-sown, food quality, winter peas are poised to fill that need. **Earn 2 CEUs in Crop Management** by reading this article and taking the quiz at www.agronomy.org/acsAdmin/education/classroom//classes/487#

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In the inland Pacific Northwest USA (PNW), dryland cropping systems are dominated by wheat. In Washington, Oregon, and Idaho, more than 6 million ac are in dryland production in regions that average less than 18 inches annual precipitation. The typical rotation is a monoculture two-year winter wheat–summer fallow rotation in areas receiving less than 15 inches annual precipitation and a three-year winter wheat–spring cereal (either wheat or barley)–summer fallow rotation in the 15- to 18-inch precipitation zone. There are few alternative, rotational crops to wheat. Although the benefits of spring-sown crops such as peas or lentils can result in a 30% increase in the following winter wheat yields, yield of the spring-sown crop itself is highly variable and often not economically viable since it matures in conditions of heat stress and terminal drought, resulting in low, unsustainable yields. There is high interest and anticipation for an economically viable broadleaf rotation crop for winter wheat, especially where summer fallow is practiced and no good alternative crop is available.



Photo by Edwin Remsburg/
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sown 4 to 6 inches deep using a deep-furrow drill to reach stored soil moisture. Wheat emergence from those depths can be problematic due to limited moisture and soil crusting from rains before emergence. However, winter peas can consistently emerge from 6-inch depths or more and have emergence force to break through most crusting conditions.

Currently, winter peas are produced on approximately 38,000 ac in the U.S. (source: USDA-NASS; see www.nass.usda.gov) and are used for cover crops, grazing, feed, and wildlife food plots. Production acres of winter peas have increased more than 50% in the past five years, and contracts are in high demand.

Austrian winter peas are small-seeded, yellow-cotyledon peas with pigmented seed coats and flowers. Austrian winter peas were first grown in the PNW in 1932. Seed was grown primarily in Idaho and then used as a green manure crop in southern states. During World War II, nitrate fertilizers were not produced, and demand and use of Austrian winter peas, as a source of N, increased. Selections from the original “land race” of Austrian winter peas led to the release of superior cultivars beginning in 1972 and continuing today. However, until recently, they have been all classified as “feed peas” due to subtle mottling on the seed coat or a greenish seed coat.

Prior to 2009, U.S. marketing regulations allowed only spring-planted peas to be sold in the food quality markets. However, in 2009, the pea classes in the Federal Grain Inspection Service grade standards were changed to allow winter peas to be marketed as smooth dry yellow peas or smooth dry green peas (USDA-GIPSA, 2009). This change in regulations allows winter peas to move in the same marketing channels as spring-planted peas—the quality characteristics of the harvested seeds, not the planting season, dictate the markets in which the crop can be sold. This allows winter peas to enter the much more economically rewarding food quality distribution channels and opens the potential for widespread winter pea production. Food quality winter pea cultivars could be sold to open commodity markets and not limited by contracts. The original Austrian winter peas are characterized by small seeds with darkly pigmented seed coats—both the size and color of the seed exclude them from being classified as food quality. In order to meet food quality, the seeds must be smooth, large (hundred-seed weight of at least 17 g), and have a clear seed coat and hilum.

Genetics of winter hardiness

Winter hardiness in peas is a complex combination of phenotypes that the plants express in response to environmental cues. When plants are screened for frost tolerance in controlled environments, they are screened only for frost tolerance at a single point in their phenology. Even though care may be taken to acclimate the plants prior to freezing, they will not experience the full range of environmental cues as field-grown plants. Differences between field and controlled conditions include diurnal variation in air temperature, differences in soil temperatures (field compared with pot), light intensity and spectral quality, and other environmental factors. Results from

Winter peas (*Pisum sativum* L.) are an alternative. Planted in late summer to early autumn, winter peas confer all of the advantages of spring-planted peas. With symbiotic Rhizobia bacteria, they fix atmospheric N, making them a low-energy and low-greenhouse-gas-emissions crop; they interrupt weed, disease, and insect cycles; have a relative low water use; and can flourish under current crop management practices with existing farm equipment. In addition, their greater yields compared with spring peas make them economically viable, and late-summer planting shifts fieldwork to avoid the vagaries, narrow planting window, and variable conditions that constrain spring-planted peas.

Winter peas are broadly adapted to dryland production in all regions where winter wheat is grown, and the improved cold hardiness of winter peas rivals that of winter wheat. Winter peas outyield spring-sown peas by 150 to 300% and mature two to four weeks earlier. Early maturity is an essential attribute for dry area crop adaptation, especially when the majority of precipitation falls in winter. After a year of fallow, winter wheat seed is commonly

controlled condition freezing tests must be interpreted cautiously.

Winter hardiness in peas is a combination of acclimation, tolerance, and avoidance. As the autumn temperatures fall, days shorten, and spectral quality of light changes, the plants become acclimated to cold temperatures. Some of the physiological characteristics that have been associated with the process of cold acclimation in peas are the accumulation of sugars in leaves, stems, and roots (Bourion et al., 2003) and an increase of the RuBisCO activity (Dumont et al., 2009). When peas that are cold acclimated do experience freezing temperatures, there is less electrolyte leakage than in non-acclimated peas, and associated QTL have been identified (Dumont, et al., 2009).

Photoperiod sensitivity and delayed transition from vegetative to reproductive growth helps peas to escape freezing events in late winter. In pea, two major genes govern the transition to reproductive growth: *Hr* and *Lf*. Plants that are dominant *Hr* are responsive to daylength and will not flower until days are 13.5 hours long (Murfet, 1973; Lejeune-Hénaut et al., 1999, 2008). Plants that are recessive *Lf* will flower as early as the eighth node (Alcade et al., 1999; Yates and Murfet, 1978). Combining *Hr* with *Lf* results in plants that flower in late April to early May, well after the last spring frosts but soon enough to mature before terminal drought and heat stresses in summer.

Early studies documented that an autumn and winter growth habit characterized by a rosette of spreading branches with short internodes was closely associated with winter hardiness (Andersen and Markarian, 1968; Markarian and Andersen, 1966) and was controlled by two genes. *Hr* enhances the rosette growth habit (Murfet and Reid, 1974).

In the past 15 years, cold hardiness of winter peas has genetically improved, and new cultivars have the cold hardiness levels of winter wheat (Fig. 1).

Insect pests

The principal insect pests affecting winter peas are the same as those affecting spring pea: pea leaf weevil (*Sitona lineatus*), pea seed weevil (*Bruchus pisorum*), *Lygus* spp. bugs, and pea aphid (*Acyrtosiphon pisum*) (Dodd et al., 2011; Horne and Bailey, 1991; Rinehold, 2015; Smart et al., 1994). Pea aphid is additionally problematic as a vector for pea enation mosaic virus (PEMV) and bean leaf roll virus (BLRV). These two viruses intermittently cause

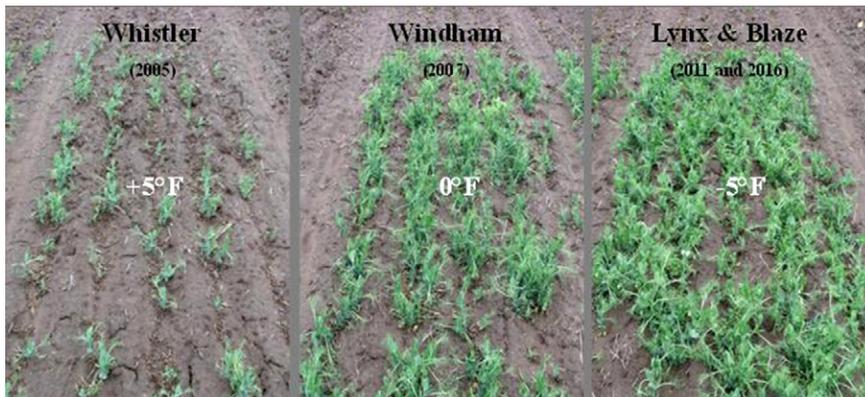


Fig. 1. Improvement in level of winter hardiness of autumn-sown winter pea cultivars ‘Whistler’, ‘Windham’, ‘Lynx’, and ‘Blaze’. Year of release in parenthesis; Hardiness at temperatures indicated. Photos by H. Nelson.

widespread destructive disease and yield losses in pea in the PNW. Pest dynamics and potential for causing injury have not been documented in winter pea and likely differ from spring-sown pea. For example, the pea leaf weevil overwinters as adults in perennial habitats in the PNW. In spring, the weevils migrate into pea fields where they feed on seedlings and oviposit (Hanavan and Bosque-Perez, 2012). The feeding can reduce plant vigor and stand counts. Feeding by the larvae on the roots and nodules in the season further reduces yield (Vankosky et al., 2011). Austrian winter peas have been tried as a trap crop for spring pea, where they are heavily attacked by pea weevil, but the effect on yield is unknown. Winter peas are well established during typical pea weevil migrations and may be more tolerant than spring pea. Current recommendations for managing pea leaf weevil (e.g. Cárcamo and Vankosky, 2011) may be not be appropriate for winter peas. Pea seed weevil appears in spring pea just prior to bloom, ovipositing into developing pods; larvae enter the pods and destroy the seeds. Winter pea blooms much earlier than spring-sown pea, potentially escaping some, but not all, of this attack.

Intermittent epidemics of aphid-borne viruses present a challenge for farmers who must make appropriate management decisions for the pea aphid to minimize virus risk. Decision support tools have been developed based on seasonal and spatial variation in virus injury and aphid monitoring to assist farmers in deciding when to treat the aphids to minimize virus injury. The tools have been provided online since 2011 (www.cals.uidaho.edu/aphidtracker) but are not designed for fall-sown pea. Winter peas are potentially exposed to virus in the fall, early spring, or both, when aphids are in flight and only winter peas are present in the landscape. If infected in the fall just after emergence, disease and injury could be severe; if infection in the spring occurs only after they



are relatively mature, when tolerance to PEVM and BLRV is expressed (Stokes, 2012), the crop may not be vulnerable to viruses. Until virus-resistant varieties of spring and winter peas become more widely available, support for aphids and viruses is needed.

In summary, research documenting insect pest pressure in winter pea has been very limited, but pests affecting spring-sown pea will certainly be present, and the severity of their effects could differ. Until more thorough study of the pests in these crops can be conducted, farmers need to be vigilant in monitoring the crop to avoid unexpected injury. In addition, production landscapes that contain significant acreage of late-summer and spring-sown pea simultaneously could, because of the more continuous presence of the crop, produce area-wide effects with new opportunities and challenges for pest management.

Diseases

Winter peas are subject to the same diseases and disease complexes as spring peas. The soil-borne diseases that are of concern include the Fusarium root rot (FRR) complex and Aphanomyces root rot (ARR). Fusarium root rot can be caused by a complex of species of *Fusarium* including *F. avenaceum* and *F. solani* (Hwang et al., 1994, 2000; Lin and Cook, 1977; Kraft and Pflieger, 2001). Sources of resistance to FRR have been identified in pea (Grünwald et al., 2003), and germplasm has been released with high levels of partial resistance (Coyne et al., 2008). This resistance is being incorporated into winter material. Typical symptoms of FRR include red to brown-

Fig. 2, top left.

Fusarium root rot on peas. Advanced lesions affecting large areas of roots and hypocotyls. **Fig. 3, right.** Aphanomyces root rot on peas.

Top: Outer root tissue sloughing off and exposing inner vascular tissue. *Middle:*

Honey-colored infected roots (right) and healthy roots (left). *Bottom:* Infected roots and yellowing lower leaves. Photos by L.D. Porter.

black belowground lesions, belowground red discolored vascular tissue, and aboveground stunting, yellowing, and necrosis (Fig. 2).

Aphanomyces root rot is caused by the oomycete *Aphanomyces euteiches* Drechs and is probably the most important disease of pea worldwide. It was first reported in the 1920s in Wisconsin and has been widely observed throughout North America (Kraft and Pflieger, 2001). Germplasm with high levels of partial resistance have been released (McGee et al., 2012), and this resistance is being incorporated into winter peas. Typical symptoms of ARR include honey-colored root and belowground stem, outer root and belowground stem tissue slough off, and yellowing of lower leaves and stunting (Fig. 3).

White mold, caused by *Sclerotinia sclerotiorum*, can be problematic on winter peas because of their typically



Fig. 4, far left. White mold. *Top:* sclerotia on the soil. This overwintering structure can survive for many years in the soil. *Middle:* sclerotia forming in the stem. *Bottom:* water-soaked lesions with white mycelium. Photos by R.J. McGee. **Fig. 5, middle.** Pea enation mosaic virus (PEMV) on pea. *Top:* enations on pods. *Bottom:* translucent foliage windows on stipules. Photos by R.J. McGee. **Fig. 6, below.** Bean leaf roll virus (BLRV) on pea. *Top:* Mild infection. Note down curling of the stipules. *Bottom:* severe infection. Photos by L.D. Porter.



very dense canopy. Symptoms include lesions on stems followed by the appearance of white fungal growth. Mouse-dropping-sized black sclerotia may form on and/or in infected tissue (Fig. 4). There is no resistance—many broadleaf crops are also hosts, and the sclerotia can overwinter in soil for many years. Management includes planting clean seed, fungicide applications, and crop rotations.

The aphid-transmitted viruses PEMV and BLRV are important diseases on pea in the PNW. Symptoms of PEMV include “foliage windows” on the leaflets and formation of enations on both leaves and pods. Pods are frequently severely distorted (Fig. 5). Symptoms of BLRV include yellow and stunted plants and downward curling leaflets (Fig. 6). Neither virus is seed-transmitted, and early infections tend to be more severe than later ones. Cultivars with resistance to one virus are available, and cultivars with resistance to both viruses will be available within three years.

A very useful disease diagnostic guide, *Pea Disease Diagnostic Series* (PP1790) (Markell et al., 2016), is available through local extension offices and the North Dakota State University Extension Service (www.ag.ndsu.edu/publications/crops/pea-disease-diagnostic-series).

Grassy and broadleaf weed control

Weed control in spring peas has evolved over the years to where control of grassy weeds has become easy and control of broadleaf weeds is acceptable in most cases. Herbicides that controlled weeds in spring peas have been brought forward by the chemical manufacturers and are now registered for use on winter peas (see labeled products in Table 1). Products labeled for use on spring peas can also be used on winter peas, but the weed spectrum that is a problem in winter peas is different from that in spring peas. The grassy weeds that are problems in spring pea production, such as wild oats (*Avena fatua*), Italian ryegrass (*Lolium perenne* ssp. *multiflorum*), and interrupted windgrass (*Apera interrupta*), are replaced by weeds such as downy brome (*Bromus tectorum*), cereal rye (*Secale cereale*), and jointed goatgrass (*Aegilops cylindrica*). The broadleaf weeds that can cause problems in spring pea production, such as common lambsquarters (*Chenopodium album*), catchweed bedstraw (*Galium aparine*), and black nightshade (*Solanum nigrum*), are replaced with pinnate tansymustard (*Descurainia pinnata*), tumble mustard (*Sisymbrium altissimum*), flixweed (*Descurainia sophia*), and other winter annual broadleaf weeds. In ad-

dition, the concern that the winter peas may suffer from winterkill if winter temperatures drop below their survival threshold limits herbicide options to postplant applications in the spring. Herbicides are normally applied shortly after crop dormancy breaks, and weather conditions at this time usually have low daytime air temperatures, which often drop below freezing during the night. These conditions lower the effectiveness of many of the registered herbicides used on peas.

Both labeled and non-labeled products have been screened alone and in combination with other herbicides. Only a few of the registered herbicides have shown efficacy on the spectrum of weed species present in the PNW. Several, not registered, herbicides have shown promise for use on winter peas, but the chemical manufacturers have been reluctant to start the process to allow these herbicides to be registered. Often these herbicides are registered for use on crops such as soybean or peanut, which have a much larger acreage base.

Currently, farmers have been relying on MCPA amine (registered in the PNW only), metribuzin, and imazamox for control of broadleaf weeds. Grassy weed control has been provided by either quizaflop-p, clethodim, sethoxydim, or imazamox. *Always check the product label for herbicides registered for use in your area, and be sure to follow the label directions as well as the recommended rates of herbicide and adjuvant on the label if provided.*

Fallow nitrogen management

Winter peas have the greatest potential to be grown in the drier climates such as east-central Washington where winter wheat is grown in fields alternating with fallow. This cropping system, winter wheat–fallow, has been the standard cropping system since hardy varieties of wheat became available in the 1890s. While winter peas have provided similar revenues to winter wheat when they are grown, the benefits from adding winter peas to this rotation becomes apparent in the years following pea production. In the fallow year after winter pea harvest, farmers

Table 1. Herbicides labeled for use on winter peas.

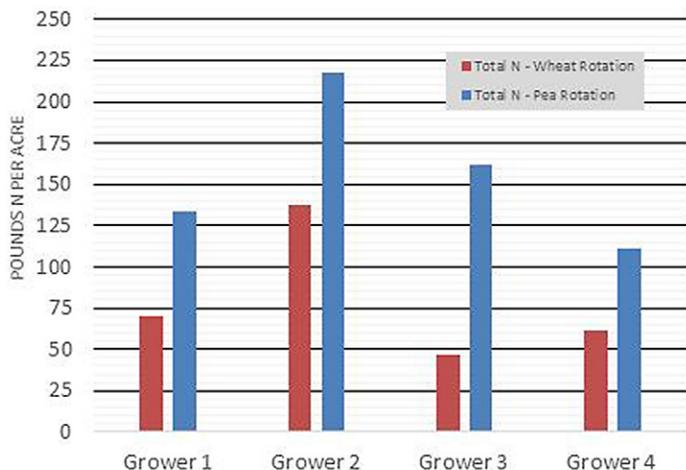
Common name	Trade name	Group	Pre-emergent	Post-emergent	Grassy weed	Broadleaf weed
Quizalofop-p	Assure II	1		X	X	
Sethoxydim	Poast	1		X	X	
Clethodim	Select	1		X	X	
Imazethapyr	Pursuit	2	X		X	X
Imazamox	Raptor	2		X	X	X
Pendimethalin	Prowl H ₂ O	3	X		X	X
Enthalfuralin	Sonalin	3	X		X	X
Trifluralin	Treflan	3	X		X	X
S-metolachlor	Dual II	4	X		X	X
MCPA amine †	MCPA	4		X		X
MCPA sodium	Chiptox	4		X		X
MCPB	Thistrol	4		X		X
Bentazon	Basagran	6		X		X
Linuron	Lorox	7	X			X
Triallate	Far-GO	8	X		X	
Saflufenacil	Sharpen	14	X			X
Sulfentrazone	Spartan	14	X			X
Dimethenamid-P	Outlook	15	X		X	X

† Only registered for use in Washington, Oregon, and Idaho.

have experienced higher-than-expected rates of nitrogen mineralization. In a study conducted in 2016 with four farmers in east-central Washington, fallow after winter pea had significantly higher residual nitrogen levels and averaged +76 lb nitrogen/ac more than the winter wheat–fallow of each farmer (Fig. 7).

The mineralization rate is 3.8× the credit projected by *Dryland Winter Wheat: Eastern Washington Nutrient Management Guide* (EB1987, see <http://bit.ly/2nEeGX9>). The nitrogen credit in that guide for previous grain and forage legume crops was developed for cropping systems that had spring peas in the rotation. Winter peas, planted in late August or early September, nodulate and fix nitrogen for 4 to 6 weeks in the fall until the crop goes into dormancy for the winter. In the springtime, when they resume growth, they will fix nitrogen for another 8 to 10 weeks until they reach the peak in nitrogen fixation during the reproductive stage, a total of 12 to 16 weeks. This compares to about eight weeks of nitrogen fixation for spring peas.

In addition, the winter wheat–summer fallow cropping system provides high amounts of residue with a high carbon-to-nitrogen ratio (C:N) of 80:1. Pea stover has a much lower C:N ratio of 29:1. The pea stover C:N ratio is nearly that needed for the diet required by soil mi-



croorganisms of 24:1. The warm and moist conditions during the pea fallow along with a food supply with a low C:N ratio promotes soil microbial activity, adding to the mineralization of nitrogen as well as many other nutrients that are released from the soil organic matter upon decomposition.

We recommend that farmers delay taking soil tests in their fallow fields for measurement of soil residual nitrogen until the end of the summer just prior to seeding their winter wheat. They should then base their application of nitrogen fertilizer on the difference between that soil test and the total nitrogen required to reach anticipated winter wheat grain yield potential.

Results from a six-year cropping systems experiment

A recently completed six-year winter pea (WP) cropping systems experiment near Ritzville, WA (11.5 inches average annual precipitation) was conducted to determine the suitability of WP in the low-precipitation zone where the winter wheat–summer fallow (WW-SF) rotation is practiced by more than 95% of farmers. The two 3-year crop rotations in the experiment were (i) WP–spring wheat (SW)–SF versus (ii) WW–SW–SF.

Averaged over the years, WP used an average of 1.2 inches less soil water than WW ($P < 0.001$). The majority of this water savings with WP occurred at soils depths below 3 ft as WP does not root past this depth. However, by late March, WP plots had only 0.5 inches more soil water than WW plots because: (i) the greater the surface residue cover, the more water will be stored in the soil (e.g., WP produces little residue compared with WW); and (ii) the drier the soil, the more overwinter precipitation will be stored in the soil. The overwinter precipitation storage ef-



Fig. 7, left. Mineralization of N in fallow following fall-sown peas and winter wheat on four farms in Washington in early May. **Fig. 8, above.** Seed quality characteristics of new food quality winter peas (PS113000287W and PS11300289W) compared with spring peas Hampton and Carousel, winter pea Windham, and Austrian winter pea Common.

ficiency in the soil averaged 55 and 69% for WP and WW plots, respectively. The end result, however, was that when SW was planted in late March, there was still greater than a half inch more soil water following WP versus following WW.

Yield of WP ranged from 1,515 to 2,820 lb/ac and averaged of 2,182 lb/ac. Winter wheat grain yield ranged from 50 to 87 bu/ac for an average 73 bu/ac over the six years. Average SW grain yield of 34 bu/ac following WP was significantly greater than 32 bu/ac following WW.

When measured in late March, soil nitrate-N values trended higher after a crop of WP compared with WW, despite the fact that zero N was applied for WP and 50 lb of N/ac was applied for WW. Nitrate-N values were 25 to 41% greater following WP versus WW.

A big benefit of growing WP in wheat-based cropping systems is the opportunity for in-crop control of winter-annual grass weeds. Another benefit of WP is its large seed size and strong “push” by the elongating hypocotyl, which enables it to emerge from deep planting depths. Experience of farmers and scientists strongly demonstrates that WP seedlings can emerge from even deeper planting depths than WW. In addition, WP seedlings easily emerge through surface soil crusted by rain showers whereas WW seedlings cannot do so.

A soil management concern about growing WP is the fact that they produce very little durable residue. Wind erosion and dust emission from agricultural soils are major environmental and air quality concerns in east-central

Washington. Wind tunnel studies during the fallow year after the oilseed crops camelina and safflower showed up to 250% greater blowing dust emissions even using best management practices for tillage-based SF compared with after WW. Personal observation suggests that WP residue decomposes at about the same rate as residue of oilseed crops. In a practical sense, this means that farmers must be especially judicious in protecting the soil after WP by either (i) recropping to the spring crop (as done in this study) or (ii) conducting no-tillage during the 13-month SF cycle.

This six-year study showed that WP has excellent production potential in the typical WW-SF region of east-central Washington. Winter peas have unsurpassed seedling emergence from deep planting depths, even when surface soils have been crusted by rain showers before emergence. Excellent WP plant stands were consistently achieved. New and better WP varieties will be available to farmers in 2018 (Fig. 8) that have cold tolerance similar to that of WW, greater yield potential than current varieties, and even better quality traits that will fetch higher prices in regional, national, and international markets. Adjusted gross returns (that included fertilizer cost savings and additional SW grain yield) for the WP rotation were equivalent to those of the WW rotation in this study.

Crop insurance considerations

Farmers who grow peas, lentils, and garbanzo beans (chickpeas) have the option to protect their production risk to grow these crops with yield coverage through the USDA Risk Management Agency (RMA) Dry Pea Policy. Farmers in RMA-approved select counties in Washington, Idaho, Montana, and North Dakota can get this coverage through their crop insurance agent where T-yields, planting dates, and cropping practices have been established. Farmers of winter peas can also take the Winter Coverage Option, again in RMA-approved counties. This coverage will give the grower several options for reseeding the field, in the event that the crop winterkills. Often, farmers of winter peas are producing peas outside of the normal production areas of spring peas and are in a county where this coverage is not automatically extended. They may still be able to get this insurance with a written agreement between their crop insurance agent and RMA. In addition, first-time farmers of dry peas will be extended 100% of the T-yield established for their county. Farmers can take a look at the approved counties and the established T-yields and approved practices at <http://bit.ly/2nrxecb>.

One problem with the RMA yield coverage for winter peas has been that the crop loss adjustment factors that have been developed correspond more closely to spring-planted peas than winter peas. The big difference between the spring-planted and winter peas is winter peas branch or tiller, where spring peas do not (Fig. 9). When a winter



Fig. 9. Branching habit of spring pea (*left*) vs. winter pea (*right*). Photos by H. Nelson.

pea plant reaches the third, aboveground vegetative node, a branch will form from the leaf axil at the first aboveground vegetative node. From these tillers, an average of 2.3 per plant will become reproductive in the spring. This branching ability allows farmers to use a lower seeding rate while still getting similar numbers of flowers that set pods. Presently, there is no allowance in the adjustment factors for the lower seeding rate and the tillering ability of winter peas. If the farmer submits a claim for a crop loss in the spring due to winterkill, the adjusted crop yield is much lower than what he or she may actually harvest by a factor very close to the average branching that has been measured.

Conclusions

Changes in marketing regulations in 2009 have made it possible to market fall-sown winter peas in the economically rewarding food quality markets, and that infrastructure already exists. Plant breeders have made important improvements in the degree of winter hardiness of fall-sown peas so that they are approximately as winter hardy as winter wheat. Plant breeders have also made significant improvements in the quality of the harvested seeds; they are indistinguishable from spring pea seeds and meet food quality standards. Including winter pea will help break weed and disease cycles and will leave more soil moisture and nitrogen for the subsequent wheat crop. In the dry areas of the PNW where the typical rotation is winter wheat–summer fallow, farmers need a broadleaf rotational crop to improve the sustainability of the cropping system. Fall-sown, food quality, winter peas are poised to fill that need. &

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