Potential Alternative Crops for Eastern Oregon

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Abstract

The winter wheat/summer fallow rotation is the most common cropping system in eastern Oregon. It is used to store winter precipitation and control weeds. This cropping system, however, destroys soil organic carbon, reduces water infiltration and thus leads to soil erosion, and is not sustainable. Conservation tillage, annual cropping, and the introduction of alternative crops are ways to improve sustainability of cropping systems in eastern Oregon. The following review briefly discusses the uses, climatic requirements, and yield potential of potential alternative crops for eastern Oregon. These crops include legumes, cereals, and crops with industrial and pharmaceutical uses. Based on this review, research should focus on evaluating potential alternative crops for suitability to eastern Oregon conditions and provide growers with information they need to integrate these crops into existing cropping systems.

Introduction

The Pacific Northwest (PNW) Columbia Plateau is semi-arid with rainfall ranging from 12 to 18 inches. About 70 percent of annual precipitation occurs from November to April during winter and water available to plants during spring and summer depends on how much water is stored in the soil. Because of steep slopes prevalent in the PNW, soil erosion is a major problem in fields that do not have sufficient residue cover. Cropping systems that improve water infiltration and storage, reduce evaporation, and increase water use efficiency of crops on a sustainable basis should be developed.

Wheat/fallow rotation is the traditional crop production system in the PNW Columbia Plateau. The winter wheat/summer fallow rotation is used on 4.5 million acres in the drier portion of the region, where rainfall is considered inadequate to produce a crop every year. This cropping system is most economical where rainfall is less than 13 inches. Summer fallowing is used to store winter precipitation and control weeds. This cropping system, however, depletes soil organic carbon and reduces water infiltration, leading to soil erosion (Rasmussen and Parton 1994). In the long-run, soil productivity decreases. Research should focus on developing biologically and economically sustainable farming systems. Conservation tillage, annual cropping, and the introduction of alternative crops are ways to improve sustainability of cropping systems in the PNW.

No-till (direct-seeding) systems increase infiltration, reduce runoff, and reduce tillage costs but adoption has been slow. This is primarily because of cultural inertia, cost of equipment, and uncertain crop yields due to weed and disease build up (Williams and Wuest 2001).

Annual cropping is limited by low rainfall and soil moisture. Planting every year, however, has the potential to reduce soil erosion when compared to summer fallow. When annual cropping includes alternative crops and spring plantings, weeds and diseases can be controlled (Williams and Wuest 2001).

Cropping systems that include alternative crops should improve soil fertility and structure and reduce weed and disease incidences. Alternative crops, however, suffer from lack of markets and stable prices and their yields have been inconsistent primarily because they are not well adapted to the environmental conditions of the PNW. Furthermore, research on their agronomy is lagging. More work should be done to evaluate the sustainability of cropping systems that include alternative crops. Below is a brief description of alternative crops that have production potential in the PNW and their uses.

Alternative Crops and their Uses

Soil productivity can be sustained by inclusion of alternative crops in rotation with wheat. Different alternative crops improve soil productivity in different ways. Alternative crops, when carefully chosen, can be used to improve soil water storage, fertility, and structure, and reduce disease incidence. Agronomic and economic assessments of alternative crops in cereal-based rotations should be conducted. Potential alternative crops for the PNW include legumes, oilseeds, and other cereals besides common wheat.

Legumes

Legumes (pulse crops) can improve the production potential of subsequent cereal crops. Legumes fix nitrogen (N) and reduce N applications for the following cereal crop. In addition legumes reduce disease incidences of other crops in rotation. However, soil erosion can be a serious problem in crop rotations with grain legumes followed by winter wheat. Legumes produce relatively little crop residue, and it is fragile and decomposes rapidly under most conditions. This problem can, however, be overcome by reduced tillage where the legume is planted in the stubble of the previous spring or winter cereal.

Legumes can be classified as cool- and warm-season crops. They are low in fat, rich in fiber and complex carbohydrates, and are good sources of vitamins. Consumption of these healthy foods has been increasing. Some pulses, most notably soybean and peas, are important livestock feed. Other legumes have pharmaceutical and industrial uses.

Cool Season Food Legumes

Cool-season legumes are long day plants, i.e., they grow vegetatively during the cool season and flower and produce seeds when daylengths are progressively longer. Examples of cool season food legumes include chickpea, faba bean, field pea, grasspea, lentil, and lupin. These legumes originated in the Near East (Smartt 1990) and spread to the cool-temperate areas of central and northern Europe, from where they found their way into the western hemisphere (Muehlbauer 1991).

Dry pea, lentil, and chickpea are produced in the Palouse region of eastern Washington and northern Idaho, while the coastal region of south-central California is of equal importance for chickpea. There is renewed interest in lupins in eastern Oregon. Lupins were first introduced to the United States in the 1930’s but production had almost disappeared by the 1960’s. Faba beans have not gained any popularity as food in the United States. They are mostly used for livestock feed either as grain or as green forage and overseas market outlets have not been developed. Scattered areas of faba bean production can be found in western Washington, irrigated areas of Montana and Wyoming, and several northeastern states.

Expanded production of the cool-season food legumes depends on increased domestic usage and the development of overseas markets. Large areas of the arid western states could successfully produce cool-season pulses if uses and outlets were developed. If ranked for their ability to produce under dry conditions, grasspea would come first followed by lentil, chickpea, pea, and finally faba bean (Muehlbauer 1993). Lupin would probably be between lentil and chickpea.

Grasspea

Grasspea (*Lathyrus sativus* L.) or chickling vetch is a creeping vine. It is widely grown in Bangladesh, India, and to a lesser extent in the Middle East, southern Europe, and some parts of South America. Grasspea is usually grown for grain but can be used for fodder. As a pulse, grasspea is very high in protein, but a neurotoxic amino acid that is present in wild and most cultivated forms has prevented it from developing into an important food legume. If the toxin is consumed in sufficient amounts it can cause the irreversible crippling disease known as lathyrism (Smartt 1990). New cultivars contain reduced toxin levels.

Grasspea has great potential in semi-arid areas of eastern Oregon where drought strongly restricts the yield of most current pulse crops. It can be used as a drought-tolerant green manure. This annual legume can provide ground cover as an alternative to summer fallow, helping to prevent wind and water erosion, as well as adding N to the soil (Small 1999). Grasspea could become an important feed grain crop in the semi-arid western states if yields can be improved and low neuro-toxin cultivars can be developed.

Lentil

Lentil *(Lens culinaris* L.*)* is widely grown in semi-arid regions of the Near East, northern Africa, and the Indian subcontinent. Lentil was widely grown in southern and central Europe but was discontinued due to difficulties associated with harvesting. Because of the plant's short stature, mechanical harvesting was impossible and farmers relied on hand pulling of the plants. The International Center for Agricultural Research in the Dry Areas (ICARDA) in Syria is now developing tall upright lentil germplasm adaptable to mechanical harvesting. Of the southern European countries, only Spain remains as a major producer of the crop. Lentil, like chickpea, has no antinutritional factors except for ingredients that cause flatulence (Muehlbauer 1993).

The first commercial domestic production of lentil took place in 1937 near Farmington, Washington. Production expanded until 1981 when nearly 222,390 acres were produced. Since then, production has stabilized at about 111,195 acres annually (Muehlbauer et al. 1985). Fluctuations in production are a response to variable export market demands, as nearly 90 percent of the crop is exported.

Lentil outperforms all other legumes except grasspea when precipitation is below 14 inches, and in the coldest climates, making it suitable for eastern Oregon. Grain yields of 300 to 1,200 lbs/acre have been observed (Rasmussen and Smiley 1994; Machado et al., *unpublished data*)

Lupin

Lupin (*L. albus* L., *L. augustifolius* L., *L. luteus* L., *L. mutabalis* L., *and L. cosentenii* L.) is a cool-season grain legume or forage crop. It is cultivated worldwide, in climates ranging from northern Europe and Russia, to the arid Australian plains and the Andean highlands. Both spring-sown and fall-sown types are grown, but only the spring types are adapted to the northern midwestern United States, northeastern United States, and Canada. Lupin is one of the few grain legumes that compares to soybean in seed protein content (Hymowitz 1990). The large seed and lack of anti-nutritional factors make lupin a potential crop for many animal feed formulations, for direct feeding, and as a human food. Care must be taken, however, to produce alkaloid-free lupins. Lupin grain is high in protein and energy, is low in fat, and has good fiber digestibility. However, because of its historically bitter seed, lupin production represents a small fraction of a percent of the grain legumes grown worldwide (Williams 1986).

Lupin was first introduced into the United States in the 1930's by USDA researchers, primarily as a green manure or cover crop in the southern Cotton Belt. By 1950, the area under lupin production had increased to over one million acres in the "Lupin Belt," the coastal plain stretching across the southeastern United States. Reeves (1991) attributed the disappearance of lupins in the 1960's to increased availability of cheap N fertilizers and lack of government support. Work to improve white lupin lines by Fred Elliott, however, continued and several new cultivars were introduced in Minnesota and Canada in the early 1980's (Putnam et al. 1991). Efforts by plant breeder Gene Aksland (Resource Seeds, Gilroy, CA), and experimental work in the PNW and Canada were important in introducing the crop to those regions in the 1980's.

Lupin has big potential for eastern Oregon. In recent experiments at Pendleton and Moro, narrow-leaf lupin varieties yielded more than 1,120 lbs/acre (Chen et al. 2001). Lupin yields in northern Idaho averaged less than 1,000 lbs/acre. Lupins can fix 168 to 224 lbs N/acre (Reeves et al. 1990). Although lupins possess an upright growth habit attractive for direct harvesting, their large seed size necessitates high seeding rates and make proper establishment with commercial small-grain drills difficult (Muehlbauer 1993). Higher seeding costs limit lupin production for green manure or forage purposes. Like soybean, lupin does not flower in northern Idaho until the moisture and temperature stress periods of July and August. No flowering problems have been shown in the narrow leaf lupins that were evaluated in eastern Oregon (Chen et al. 2001). No serious insect problems have been observed, but powdery mildew and bacterial pod blight have been observed on lupin crops grown in northern Idaho.

Chickpea

Chickpea *(Cicer arietinum* L.*)* is an annual plant that generally requires a cool season. India is the major producer of chickpea with nearly 17.5 million acres under production (Smithson et al. 1985). Chickpeas are classified as either *desi* (small seeded) or *kabuli* or garbanzo (large seeded) types. The *desi* types predominate in the Indian subcontinent while the *kabuli* types predominate elsewhere. About 15,000 acres of chickpea are produced annually in California and the Palouse region of eastern Washington and northern Idaho, although there is scattered production in several other western states (Muehlbauer 1993). *Kabuli* types dominate American production because of their high value for use as an ingredient in salad bars; however, there is a small but steadily increasing production of *desi* types. The small amount of *desi* chickpeas produced is currently marketed to ethnic communities in large cities, but there are prospects of increasing production for export (Muehlbauer 1993).

Kabuli chickpeas offer higher return than traditional peas or lentils (Murray et al. 1987). Both domestic and export markets exist. The introduction of the California cultivar 'UC-5', combined with good market development, led to a developing chickpea industry in northern Idaho in the early 1980's. Two cultivars, 'Lyons', and 'Aztec', were developed and released by the University of Idaho to expand existing markets (Auld et al. 1985). Chickpea is drought tolerant, which is attributed to its deep taproot that can grow as deep as 6.6 ft, and is therefore suitable for the semi-arid conditions of eastern Oregon. Chickpeas can be grown to maturity from March to June. Grain yields of 923 and 1,060 lbs/acre have been obtained by *kabuli* and *desi* chickpeas, respectively (Corp et al. 2004).

Chickpea is susceptible to Ascochyta leaf blight (*Ascochyta rabiei*), a seed-borne disease is that has caused catastrophic losses to this industry in recent years. A self-imposed industry moratorium on chickpea production was enforced in 1988 and 1989 to reduce disease inoculum levels. Adoption of field and seed sanitation standards combined with resistant varieties is necessary for the continued production of chickpeas. The cultivars 'Dwelley' and 'Sanford' developed and released in 1994 by the USDA-ARS in cooperation with Washington State University, the University of Idaho, and Oregon State University have good resistance to Ascochyta leaf blight.

Field Pea

Field pea *(Pisum sativum* L.*)* is the most widely grown cool-season pulse. It has a wide range of uses from dry pulses to succulent fresh peas to edible podded types, and has the highest average grain yield (1,798 lbs/acre). The production of field pea is increasing in Europe, Canada, and Oceania, where the crop is now being produced for animal feed. Domestic production of field pea is estimated at 344,087 acres and includes dry pea, processing pea, seed pea, and Austrian winter pea (NASS 2004).

Winter pea has been grown in northern Idaho for over 50 years, but increased disease and insect pressures threaten continued production. Fall-planted legumes fix N and provide winter cover to help reduce soil erosion (Murray et al. 1987). Winter peas can be harvested for seed, combined with winter cereals for silage production (Murray et al. 1985), grown for green manure to restore depleted soil organic matter (Auld et al. 1982, Sattell 1998), or combined with winter cereals for harvesting as a multiple seed crop (Murray and Swensen 1984). Commercial seed yields have varied from 1,120 to 3,808 lbs/acre during the past 10 years. Improved cultivars (Auld et al. 1983) and improved cultural management recommendations (Murray et al. 1984b, Murray et al. 1987) have ensured continued production of winter peas in northern Idaho. Up to 174,100 acres of Austrian peas were grown in the United States in 2003 (NASS 2004).

Field pea is adapted to temperate and sub-tropical environments and is currently produced in both western and eastern Oregon (Sattell 1998).

Faba Bean

Faba bean *(Vicia faba* L.) is a cool-season grain legume that originates from Europe. It can be used for both human and animal consumption and does not contain any toxins. Like lupin, most faba bean varieties possess a large seed size that increases production costs and establishment problems with existing small grain equipment (Kephart et al. 1990). Faba bean seedlings are susceptible to feeding damage by pea leaf weevils (*Sitona lineatus* L.). Several foliar and seed blights indigenous to spring pea production areas will also infect faba beans. Faba bean seed yields have been as high as 2,016 lbs/acre, but inconsistent yields and poor market opportunities have limited production. Winter-hardy faba bean cultivars mature earlier and may produce more consistent yields under northern Idaho conditions (Kephart et al. 1990).

Evaluation of winter-hardy faba bean cultivars possessing smaller seed size was initiated in the fall of 1988. Faba bean production in the United States is limited. In some areas of the humid northeast and in western Washington and Oregon, the crop is occasionally produced for green forage. Faba bean grows best under cool, moist conditions but does not tolerate heat well. Information on the agronomy of faba bean in Oregon is available (Sattell 1998).

Warm-Season Grain Legumes

Soybean [*Glycine max* (L.) Merr.], peanut (*Arachis hypogaea* L.), common bean (*Phaseolus vulgaris* L.), mung bean [*Vigna radiata* (L.) Wilczek.], and cowpea [*Vigna unguiculata* (L.) Walp] are warm-season pulses better adapted to humid regions. The warm-season pulses are characterized by epigeal germination, a period of rapid vegetative growth, followed by flowering when daylengths become progressively shorter. Because of the flowering requirement, only day-neutral warm-season grain legumes that can tolerate cool seasons can be grown in eastern Oregon.

Soybean is the only warm-season legume that can tolerate cool-season conditions. It is used in the manufacture of edible oils, and in industrial products such as paint, varnish, resins, and plastics. Soybean meal is an important livestock feed. Efforts have been made to grow soybeans in the PNW with limited success. Day-neutral soybean cultivars developed for production in southern Canada expressed delayed flowering and maturation due to cool night time temperatures often experienced throughout the growing season in northern Idaho (Auld et al. 1978). Delayed maturation exposed soybeans to fall precipitation that reduced crop quality. Late maturation also interfered with establishment of fall-sown grain or cover crops. Recent evaluations in eastern Oregon demonstrated that soybeans emerged under cold temperature in spring, and survived the dry and hot summer months (Payne 1999). However, the yields were low (306 lbs/acre). More variety evaluations are needed to identify adaptable varieties. As soybeans require processing for their use as a feed grain or oilseed crop, market potential in the PNW is limited by the lack of processing facilities.

Oilseeds

Oilseeds tend to be higher-value crops than cereals, and are useful as alternatives in crop production and market diversification. Rapeseed, mustard, safflower, and sunflower seed are considered to be major oilseed cash crops, especially when grain markets are poor.

Rapeseed

Rapeseed or canola (*Brassica napus* L.) is an oilseed crop belonging to the mustard family. Winter rapeseed is sown in the fall and flowers in spring when daylength is increasing. Spring rapeseed is sown early in spring and seed in summer. Winter rapeseed has shown great potential for adaptation to the PNW. Commercial cultivars have been developed with reduced glucosinolate levels in their meals and with improved fatty acid compositions to enhance their industrial and edible oil market values (Auld et al. 1987a, Auld et al. 1987b). Winter rapeseed provides excellent soil erosion control, and reduces disease problems in cereal and legume rotation crops (Kephart et al. 1990, Morra et al. 1996). The agronomy of growing winter rapeseed including cultivar selection, seeding rates, planting dates, row spacings, weed control, soil fertility, and harvesting have been developed in the PNW (Murray et al. 1984a, Wysocki et al. 1991, Brown and Wysocki 2002). Grain yields as high as 3,600 lbs/acre have been produced in eastern Oregon (Wysocki et al. 1991). Spring rapeseed is not competitive with existing rotational crops in the PNW. However, breeding for superior and adaptable spring rapeseed is underway (Brown and Wysocki 2003).

Seed of rapeseed is crushed to produce an oil selected for two distinct uses, edible oil for human consumption (salad and cooking oils, margarine and shortening), or industrial oil for producing synthetic lubricants, varnishes, and plastics. The mealy residue after the oil is extracted can be used as a high-protein livestock feed supplement. When used as a green manure crop, the elevated glucosinolate levels found in the green tissue of specific cultivars suppress soilborne pathogens of cereals, potatoes, and legumes (Vaughn 1999). Winter rapeseed can produce 5.6 to 11.2 tons of dry forage/acre with 9 to 12 percent protein levels. Rapeseed oil could also serve as alternative fuel oil in times of emergency (Peterson et al. 1988). Whole rapeseed is exported to several Asian markets, particularly Japan. Small domestic markets exist for industrial rapeseed shipped to Midwest processors.

Mustard

Mustard (*Brassica juncea* L.) is a cool-season crop that can be grown in a short growing season. Varieties of yellow mustard usually mature in 80 to 85 days whereas brown and oriental types require 90 to 95 days. Mustard, especially the brown and oriental types, has a partial drought tolerance between that of wheat and rapeseed. Moisture stress caused by hot, dry conditions during the flowering period frequently causes lower yields.

Mustard can be grown for its leaves or seed. The leaves of mustard greens are used in salads or eaten fresh, canned, or frozen. Mustard seeds can be crushed to produce edible oil that also can be used for hair oil and lubricants. The oilseed, however, is unpopular in livestock feed and vegetable markets of North America because of its strong flavor. Mustard seed and seed products are used in meats, sausages, processed vegetables, and relishes (Simon et al. 1984). White mustard is generally used for flavoring, and black and brown mustards are generally used for aroma. Mustard seeds are processed to yield mustard flour, from which table mustard and other condiments are made. Prepared English and French mustards are usually made from brown mustard seeds, to which are added capers, white wine, and vinegar (Simon et al. 1984). Mustard is also used medicinally as a folk remedy against arthritis, rheumatism, inflammation, and toothache.

Cultivars of mustard evaluated in the PNW (northern Idaho) were developed in Canada and North Dakota for areas with greater summer rainfall. Experimental yields in the PNW range from 560 to 2,200 lbs/acre (Shelton 1999, Schillinger et al., 2002, Brown and Wysocki 2003). Small contract acreages of spring mustard are grown in the region for the condiment industry. Mustard, like rapeseed, suppresses diseases in cereal-based rotations (Vaughn 1999).

Safflower

Safflower (*Carthamus tinctorius* L.) is an annual oilseed crop adapted to cereal grain areas of the western Great Plains. It is a versatile crop; it can be grown for edible oil, meal, or whole seed for dairy cattle, birdseed, and oil for industrial uses. Because of its high linoleic acid content, safflower commands a premium price among edible oils, and is competitive with canola and olive oil.

Safflower is normally sown in April or early May and blooms and sets seed during periods of declining soil moisture and high temperatures in July and August. Despite the conditions, yields of 2,576 to 3,136 lbs/acre have been obtained by commercial production. Safflower has a deep taproot (7.9 to 9.8 ft) which enables it to extract water from deep in the subsoil. As a result, safflower is the most heat and drought tolerant of the alternative agronomic crops commercially available (Kephart et al. 1990). These properties make safflower suitable for production in eastern Oregon. Safflower has been grown periodically in the PNW for the past 30 years (Auld et al. 1987c, Hang et al. 1982, Murray et al. 1981). In eastern Oregon, safflower grain yields of 544 to 1892 have been obtained (Rasmussen and Smiley 1994; Machado et al. *unpublished data*). In rotation, safflower stubble provides excellent snow trapping for good soil and water conservation in combination with other conservation practices. However, rotations should be carefully planned to reduce the impacts of a dry soil profile following safflower to the subsequent crop. A small number of safflower acres are contracted each year in northern Idaho to serve California crushers. Development of earlier maturing cultivars could improve yield potential of safflower in the PNW.

Sunflower

Sunflower (*Helianthus annus* L.) is the world's second most important source of edible oil. The oil is used for cooking, margarine, salad dressings, lubrication, soaps, and illumination. The oil is also used with linseed and other drying oils in paints and varnishes. Decorticated press-cake is used as a high-protein food for livestock. Kernels are eaten by humans raw, roasted and salted, or made into flour. Poultry and cage birds are fond of raw kernels. Flowers produce a yellow dye. Sunflower is used for fodder, silage, and green-manure crop. Hulls provide filler in livestock feeds and bedding (Duke, *unpublished manuscript*).

Sunflower is grown in semi-arid regions of the world. It is tolerant of both low and high temperatures but more tolerant of low temperatures. Sunflower seeds will germinate at 39°F, but temperatures of at least 48°F are required for satisfactory germination. Seedlings in the cotyledon stage have survived temperatures as low as 23°F. At later stages freezing temperatures may injure the crop. Temperatures less than 28°F are required to kill maturing sunflower plants (Putnam et al. 1990). Sunflower can grow under temperatures ranging from 64 to 91°F, but optimum temperatures for growth are 70 to 79°F. Extremely high temperatures have been shown to lower oil percentage, seed fill, and germination. Sunflower is insensitive to daylength, and photoperiod appears not to be critical in choosing a planting date or production area in the temperate regions of North America (Putnam et al. 1990).

Sunflower often produces satisfactory yields under drought conditions detrimental to other crops. This is probably due to its extensively branched taproot that can extract soil water from about 6.6 ft in the subsoil. A critical time for water stress is the period 20 days before and 20 days after flowering (Putnam et al. 1990). The drought tolerance of sunflower, combined with its tolerance for low and high temperature and daylength insensitivity, makes it suitable for production in eastern Oregon. Grain yields in recent trials conducted in eastern Oregon ranged from 400 to 1,200 lbs/acre (Wysocki, *unpublished data*; Machado et al., *unpublished data*). Commercial sunflower hybrids can be grown in the warmer dryland areas of northern Idaho (Murray et al. 1978, Murray et al. 1986). Late maturity, limited production experience, lack of suitable equipment, and dry, hot summers have limited the seed production potential of sunflowers. Sunflower silage production has been more successful. Dryland sunflower silage yields adjusted to 70 percent moisture content have averaged nearly 30 metric tons/ha at Moscow, Idaho from 1978 to 1980. Feeding trials have shown sunflower silage is acceptable forage for growing beef steers and dairy heifers, and for dairy cows in mid to late lactation (Kephart et al. 1990).

Cereals

Cereals also can be included in wheat-based rotations. Some cereals tolerate drought more than wheat and can utilize water in different rooting zones. Cereals that may be included in rotation include durum wheat, barley, triticale, rye, oats, and sorghum. Other alternative wheat cereals that need to be evaluated for adaptability to conditions in eastern Oregon include durum wheat, spelt wheat, einkorn, emmer, and kamut.

Durum Wheat

Durum wheat (*Triticum turgidum* L.) has an amber-yellow endosperm (from which semolina is produced) and unlike the white endosperm of common wheat, pasta from durum semolina is amber colored. The flavor and cooking qualities of durum pasta are superior and durum wheat is preferred for the production of pasta products, such as spaghetti and macaroni, and for couscous, the staple food in North Africa (Small 1999).

Durum is adapted to dry climates, with hot days and cool nights, and does well under dry conditions. About 8 percent of the world's wheat production is durum wheat. The leading producers of durum wheat are the European Union, Canada, and the United States. In North America, durum wheat is most suited to western North Dakota and southern Saskatchewan. Durum wheat, as a crop, compares to common wheat much as alternative and new crops do. It is a relatively high-value commodity with a more stable future in Canada than common wheat. The increasing popularity of pasta with stronger and less elastic gluten has increased the interest in durum wheat. Available varieties in eastern Oregon are spring types whose yields are poor. Winter types have been developed by the Oregon State University (OSU) breeder, Dr. J. Peterson, but they lack winter hardiness. More work to develop high yielding and winter hardy durum varieties is needed.

Spelt wheat

Spelt wheat (*Triticum spelta* L.) is referred to as “covered wheat” since the kernels do not thresh free of the glumes or the lemma and palea when harvested. Spelt wheat is used primarily as an alternative feed grain to oats and barley. Food manufacturers in the United States have begun to use spelt to meet the nation's increasing demand for pasta and high fiber cereals. Spelt also can be used in flour and baked goods to replace soft red winter wheat. Spelt is generally more winter hardy than most soft red winter wheat varieties, but less winter hardy than most hard red winter wheat varieties. There is very little evidence that any spring types of spelt exist. Several thousand acres are cultivated in the United States.

Einkorn

Einkorn (*Triticum monococcum* L.) is also a "covered wheat". Einkorn flour is high in protein, ash, carotene content, and has small flour particle size when compared to the modern bread wheats. Dough characteristics of the einkorn accessions are significantly inferior to the modern wheats. The gluten strength is similar to that of soft wheats, but it remains sticky, with a low water retention capacity (Stallknecht et al. 1996). Einkorn is cultivated in harsh environments and on poor soil. The protein and yield of einkorn is equal to or higher than barley and durum wheat when grown under adverse growing conditions.

Emmer

Emmer (*Triticum dicoccum* L.), like spelt and einkorn, is a "covered wheat". In the early 1900's emmer was grown throughout the Midwest and western United States. Emmer yields exceeded yields of barley, oats, and wheat cultivars in years with less than favorable growing conditions, and produced equal or lower yields when growing conditions were more suitable for cereal production (Stallknecht et al. 1996). Emmer is grown for grain that is used as cattle feed, replacing either oats or barley in feedlot rations. Protein levels of emmer are higher than oats or barley. Breads produced from whole grain flour of emmer are heavy textured.

Kamut

Kamut (*Triticum turgidum* L.) kernels are twice the size of wheat kernels and are characterized by a distinctive hump shape. Kamut wheat is a specialty cereal that is marketed primarily through health food outlets. Over 70 processors list more than 100 Kamut products in the United States and Canada under regulation of the Kamut Association of North America (KANA), and the Kamut Association of Europe (KAME). Kamut products include whole grain flour, breads, hot and cold cereals, pastas, and chips, in addition to a green plant dehydrated product. Kamut grains have higher protein when compared to wheat grown under similar conditions. Kamut products made from whole grain flours have a mild, nutty flavor. Individuals who experience certain types of allergic reactions to products made from common wheat are able to eat Kamut products (Stallknecht et al. 1996).

Triticale

Triticale *(×Triticosecale* Widdmark) is the stabilized hybrid of wheat (*Triticum*) and rye (*Secale*). Triticale can be successfully produced in areas where wheat performs poorly, particularly on cold and infertile soils, extremely sandy soils, soils with high levels of boron, salty soils, acidic soils, manganese-deficient soils, and dry soils. The milling and baking quality of triticale grain is inferior to bread-making wheat and to durum wheat for macaroni, but it is often considered superior to rye. Globally, triticale is used primarily for livestock feed. In Mexico, triticale is used mostly for whole-grain breads and tortillas. In the United States, triticale is grown mostly for forage, but there is a small market for pancake mixes and crackers. Ethanol plants will pay a premium for triticale over barley since it has more starch and no hull, making alcohol production more efficient. Winter triticale is a higher-yielding, earlier-maturing alternative to spring triticale for short-season areas. In Oregon, winter triticale yields range from 67 to 190 bu/acre (Karow 2000a, 2001a, 2002).

Barley

Barley (*Hordeum vulgare* L.) is the fourth most important cereal in the United States. About 50 percent is used for livestock fodder and 37 percent for the brewing industry (80 percent for beer, 14 percent distilled alcohol, and 6 percent malt syrup; Duke, *unpublished manuscript*). Barley flour can be used instead of wheat to make bread.

Barley is widely cultivated in all temperate regions of the world and in the high mountain regions of the tropics. It is reported to tolerate alkali, aluminum, disease, drought, frost, grazing, hydrogen fluoride, low and high pH, heat, insects, nematodes, smog, sulfur dioxide, and waterlogging (Duke 1978). Barley has a shorter growing season than wheat or oats and can be grown at higher latitudes. Barley is not particularly winter-hardy, so most is grown as a spring crop. Average optimum temperature for growth is 60–63°F. Barley is grown on soils that are too light or otherwise unsuitable for wheat cultivation and does well on light or sandy loam soil. Barley can be grown following winter wheat in eastern Oregon. In recent variety evaluations, spring barley yields ranged from 1,074 to 5,030 lbs/acre (Karow 2000b, 2001b, 2003).

Oats

Oats (*Avena sativa* L.) are cultivated for the grain, hay, and pasture. Oats are used for cereals, cakes, biscuits and other pastries, for making oat flour, and as a source of oil. Oat straw is used as energy fodder, but mostly for bedding purposes because of its excellent absorbent qualities (Duke, *unpublished manuscript*). In the United States, oats are used for pasture, silage, and hay, and especially as a cover crop to protect soil on marginal land subject to erosion, and as a nurse crop to protect newly planted forages.

Oats grow under moist to very dry conditions. The crop can tolerate annual precipitation of 8 to 72 inches, annual temperatures of 41 to 79°F, and pH of 4.5 to 8.6 (Duke, *unpublished manuscript*). Winter oats evaluated in Oregon produced from 1,568 to 4,457 lbs/acre (Karow 2000a) and spring oats produced from 540 to 4,440 lbs/acre (Karow 2003).

Rye

Rye (*Secale cereale* L.) is grown for the grain that is used to make flour, the importance of which is second only to wheat. The grain also is used to make Canadian and United States whiskies. Roasted grains can be used to substitute for coffee. Rye grains can be used for livestock feed when mixed with other cereals. The crop also can be grown as pasture and can be used as green manure and cover crop, hay, and silage with crimson clover. Rye straw is used as packing material for nursery stock, bricks and tiles, for bedding, paper manufacture, archery targets, and mushroom compost (Duke, *unpublished manuscript*).

Rye is an extremely hardy plant, and is often grown where other grains will not grow. The crop grows well on infertile, submarginal areas and on sandy soils. Rye can grow in areas with annual precipitation that ranges from 8.8 to 70 inches and annual temperatures of 40 to 70°F. Unfortunately rye is now considered a weed in most of eastern Oregon.

Buckwheat

Buckwheat (*Fagopyrum esculentum* Moench) is native to temperate East Asia, and has proven itself to be widely adapted around the world. Japan is the major importer of buckwheat. In Japan, buckwheat flour is employed in combination with wheat flour to prepare buckwheat noodles (soba), a traditional dish. Ground leaves are sometimes added to the buckwheat flour, producing a green noodle. Buckwheat also can be grown as a green manure crop, companion crop, cover crop, and as a source of dark buckwheat honey. The grain and straw can be used for livestock feed, but the nutritive value is lower than that of cereals. The protein in buckwheat flour is of exceptional quality, containing a high amount of lysine, which is deficient in cereals. The groats (dehulled seed) or flour are also used to make other foods. Buckwheat flour is low in gluten content and is usually mixed with wheat flour for bread, pancakes, noodles, and breakfast cereals. Groats and grits (groat granules) can be used for porridge and other breakfast cereals. Dehulled groats can be baked or steamed and eaten as a vegetable like rice, or used in appetizers, soups, salads, breads, and desserts (Small 1999).

Buckwheat is a broadleaf cereal marginally adapted to the warmer dryland cereal production areas of northern Idaho (Auld et al. 1986). Buckwheat is more drought-tolerant than many other alternative crops, but is sensitive to frosts. Buckwheat can be used as a cover crop or green manure crop (Sattell 1998). Ways to increase its productivity and its economic value should be investigated.

Grain Sorghum

Grain sorghum (*Sorghum bicolor* L. Moench) is a warm-season summer annual with poor adaptation to the winter rainfall cycle and cooler temperatures of the PNW. The earliest maturing hybrids obtained from Midwestern states have failed to produce mature seed in northern Idaho (Kephart et al. 1990). Sorghum is a drought-tolerant crop and may do well in the PNW if varieties that can germinate under cooler conditions are developed. In eastern Oregon, grain yields of 267 to 1,047 lbs/acre have been obtained (Payne 1999).

Crops with Pharmaceutical and Industrial Uses

During the last decade, more agronomic research has been directed at increasing the production of new and alternative crops and their by-products for industrial and pharmaceutical use. Some of the under-exploited temperate industrial and fiber crops include meadowfoam, flax, crambe, kenaf, lesquerella, cuphea, euphorbia, vernonia, grindelia, hesperaloe, hemp, and sunnhemp.

Meadowfoam

Meadowfoam (*Limnanthes alba* Hartw.) is a winter annual that originates from and is adapted to the PNW. Meadowfoam development was made possible by USDA efforts in the early 1950's. Meadowfoam is cultivated for its rare oil, 95 percent of which is made up of C:20 or C:22 monoene or diene fatty acids (Kleiman 1990). Such fatty acids can be used in cosmetics, specialty lubricants, and polymers (Carlson et al. 1992). The only active crop research program is at OSU in cooperation with the OMGA and Fanning Corp. The crop is native to western Oregon (where it is grown in the Willamette Valley) and northern California. Meadowfoam should be well adapted to areas with cool soils at planting, cool and moist weather during vegetative growth, and warm, dry weather at harvest. The crop should be evaluated for suitability to eastern Oregon conditions.

Flax

Flax *(Linum usitatissimum* L.) was grown in Oregon in the 1940's (Hurst et al. 1953) but was eliminated in the 1950's by the reintroduction of European flax, the increase in cotton use in textiles, and the development of petroleum-based fibers (nylon) (Roseberg 1996). Interest has been recently revived mainly due to restrictions on stubble burning from grass seed production; these restrictions have caused problems in terms of weed control, insect, and disease cycles (Roseberg 1996). Inclusion of flax (a dicot), in grass-based rotations would provide disease breaks and allow use of alternative herbicides while providing a cash crop for growers. Flax produces fiber in stems that is used in making fine linens for clothing, draperies, and furniture. Medium fibers are used for canvas and geo-textiles, while short fibers are used for paper and sacking. Oil (linseed) is produced in flax seeds.

Flax can successfully be grown in western Oregon. The crop grows in areas that have cool, moist spring weather followed by warm summers, conditions that also prevail in eastern Oregon. Oregon statewide average yields from 1925 to 1951 ranged from 1,456 to 5,712 lbs/acre dry matter (Hurst et al. 1953). Grain yields obtained from 2002 and 2003 in eastern Oregon ranged from 200 to 400 lbs/acre (Machado, *unpublished data*). Higher yielding varieties should be developed and the agronomic practices should be improved.

Crambe

Crambe (*Crambe abyssinica* Hochst.) is a cool-season annual originating from Ethiopia. The crop has been raised in large areas in North Dakota. The oil from crambe seed is high in erucic acid that is used to manufacture synthetic lubricants and plastics. Crambe yields have averaged 2,016 to 2,464 lbs/acre in trials conducted at Moscow, Idaho in 1983 and 1984. Average seed oil content has been 35 percent. Existing cultivars lack uniform maturity, edible meal characteristics, and they shatter easily. Commercial oilseed crushing facilities for crambe are not currently available in the region.

Kenaf

Kenaf (*Hibiscus cannabinus* L.) was first cultivated in Africa and made its way to the United States in the 1940's largely through the efforts of the USDA's Search for New Pulp Fibers program (Rosenburg 1996). Kenaf fibers are used for making rope, sacking, twine, and matting. The fibers could potentially be used for newsprint, carpet backing, and as a composite for boards or other structural materials. The newsprint market in the United States is huge but kenaf must compete with wood pulp in this market. It is, however, cheaper to process kenaf than wood.

Highest yields of kenaf can be produced when mean daily temperatures are between 72° and 86°F, monthly precipitation between 3.6 and 11 inches and relative humidity (RH) between 65 and 85 percent (Rosenburg 1996). Some work on kenaf has been done in southern Oregon where average yields of 6,720 and 13,440 lbs/acre stem dry weight were obtained in the Willamette Valley and the Rogue Valley, respectively. Experiments to evaluate kenaf in eastern Oregon should be conducted.

Lesquerella

Lesquerella (*Lesquerella fendleri* L.) is a perennial plant of the Brassicaceae family that is produced as an annual for seed oil high in hydroxy fatty acids. The oil is used for specialty lubricants, heavy-duty detergents, inks, and coatings (Roseberg 1996). Lesquerella is well adapted to semi-arid locations and may be adapted to the PNW. It is planted in October and seeds develop between March and May. Lesquerella is not being produced commercially. Some small plot studies have been done in southwestern Oregon and plot yields ranged from 504 to 1,120 lbs/acre.

Cuphea

Cuphea (*Cuphea spp.*) is an oilseed crop that is native to Mexico and Central and South America. Many cuphea species have oils rich in capric, lauric, caprylic, myristic, or other medium chains fatty acids (MCFAs) (Knapp 1990, Roseberg 1996). Lauric acid is used in soaps and detergents and capric, caprylic, and myristic acids are potentially useful in industrial or nutritional applications. Cuphea is not produced commercially. The United States relies on imports of coconut and African oil palm that are rich in MCFAs (Knapp 1990, 1993). Almost all Cuphea species are wild, and seed shattering and dormancy are major obstacles to domestication (Knapp 1993). Efforts are underway to domesticate Cuphea using non-shattering cultivars (Knapp 1993). Warm weather with sufficient moisture favors vegetative growth. Cuphea is likely to grow in the Midwest and northwestern United States.

Euphorbia

Euphorbia (*Euphorbia lagascae* [Spreng]) is an herbaceous annual plant native to Spain. The seeds are potentially a source of epoxy acid that is used for adhesives, plasticizers, industrial coatings, varnishes, and paints. Lines with slightly earlier maturity may have potential in North Dakota. (Berti and Schneiter 1993). There is no commercial production at present. Work done at Corvallis and Medford, Oregon (1993-1995) indicate that seed yields from 1,187 to 3,136 lbs/acre can be obtained. Results from these studies indicate that euphorbia can be successfully grown in the PNW. The major problem with euphorbia is its violent seed shattering habit that makes it difficult to harvest the seed. Recently, chemically induced, non-shattering mutants have been developed in Spain.

Vernonia

Vernonia (*Vernonia galamensis* L.) or ironweed is one of 6,500 wild plant species screened by the USDA for production of desirable seed oils. This potential oilseed crop is native to eastern Africa. It is an annual herbaceous plant of the Compositae (Daisy) family. Vernonia seed contains about 40 to 42 percent oil of which 73 to 80 percent is vernolic acid. Vernonia can be used for epoxies for manufacturing adhesives, varnishes and paints, and industrial coatings. The plant could also serve as a natural source of plasticizers and stabilizers (binders) for producing polyvinyl chloride (PVC plastic), which currently is manufactured from petroleum. Vernonia is not produced commercially in the United States. Very little is known about vernonia's agronomy. The plant is fairly drought tolerant but requires a long season. Production areas would likely include much of the temperate United States.

Grindelia

Grindelia (*Grindelia camporum* [Greene]) is native to the San Joaquin Valley, Sacramento Valley, and adjacent Coast Range of central California. It has the ability to grow and flower primarily in the hot, dry summer months. Resins from various species of grindelia have been patented for use in adhesives, rubber, coatings, textiles, and polymers. Grindelia resins could provide a potential alternative source of diterpene resin acids for use in inks, sizings, adhesives, and other naval stores products. Naval stores is a generic term for a large class of chemicals that include turpentine, fatty acids, rosins, and their derivatives. Rosin is a complex mixture of diterpene resin acids that have wide and diverse industrial applications. Domestic supply of high-quality wood rosin, which is extracted from aged pine stumps, has disappeared. The recovery of gum rosin by tapping living pine trees is very labor intensive, and production within the United States has declined to nearly zero. The United States' market has required more than 1.1 billion lbs of rosin in the recent past (Hoffmann and McLaughlin 1986). Grindelia is not produced commercially in the United States. A few trials were conducted in southern Oregon from 1992 to 1994 and 4,144 to 4,928 lbs/acre of resin were obtained (Roseberg 1996). Grindelia is likely to grow in the PNW.

Hesperaloe

Hesperaloe (*Hesperaloe funifera* [Koch]) is a native of the Chihuahuan Desert region of northern Mexico. It produces strong fibers (fiber bundles) that are used in northern Mexico for cordage products. The fibers have a potential use in paper-making. Both *H. funifera and H. nocturna* produce long fibers that are comparable to those of softwoods in their length but are less than half as wide. The fibers of hesperaloe produce paper with exceptional tensile and tear strength that could be used in specialty papers with high-strength requirements, such as currency papers, bible papers, tea bags, and filters. The fibers also can be blended with other fibers to increase the strength and improve the texture of a variety of paper products, including writing papers, tissue and towel products, and papers manufactured using secondary (recycled) fiber (Roseberg 1996).

Hesparaloe is not grown commercially in the United States. Areas of its adaptation are not yet known. Small plot studies have been done in southern Oregon from 1992 to 1994. The crop survived the conditions in southern Oregon and produced about 10,800 lbs/acre fresh weight (Roseberg 1996).

Sunn Hemp

Sunn hemp (*Crotalaria juncea* L.) produces a bast fiber similar to kenaf that could be used in pulp and paper applications (Dempsey 1975, Cook and White 1995). The fiber is used in twine, rug yarn, cigarette and tissue papers, fishnets, sacking, canvas, and cordage. Sunn hemp is a legume that is widely grown throughout the tropics as green manure, the dried stalks and hay being used as forage for livestock. Although reported to be poisonous to livestock, seeds are fed to horses in the Soviet Union and to pigs in Zimbabwe.

Unlike kenaf, it is highly resistant to root-knot nematodes and thus can be grown in some areas where kenaf cannot (Cook and White 1995). Sunn hemp is fairly drought tolerant, can grow in marginal soils, and, being leguminous, has low N requirements. Although generally considered to be a tropical or subtropical crop, it is drought resistant and has a wide range of adaptation to soil types.

Conclusions

The detrimental effects of the traditional wheat/fallow rotation that is commonly practiced in eastern Oregon can be alleviated by the introduction of alternative crops that reduce or replace the fallow. The crops briefly discussed above must be further evaluated for their contribution in the diversification of eastern Oregon cropping systems, enhancement of human nutrition, and to rural and regional economies. To introduce alternative crops, preliminary evaluation trials should be conducted to generate sufficient management information to permit pilot production of promising crop species. More extensive research is then conducted for species showing greatest commercial potential. Research is needed to determine how well the new crops perform in conventional and no-till cropping systems, with specific emphasis placed upon (1) planting date, planting depth, and stand establishment; (2) rooting depth and water use; (3) organic matter build-up and soil structure; 4) weeds, arthropod, and disease control, and 5) influence on yield and profitability of the rotations. This information will assist farmers in determining the contribution of alternative crops in cropping systems and provide a database for enhancing the management of alternative crops in both the short and long term. Extension programs should complement research efforts to assure successful production of these crops by area growers. The economic feasibility studies and the search for potential markets should accompany both research and extension efforts.

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