ALTERNATE CROPS FOR EASTERN OREGON: RESEARCH

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Table of Contents

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.

Chickpeas (*Cicer arietinum)*

Description

Chickpea *(Cicer arietinum* L.*)* is an annual, cool-season crop that grows well when air temperature is between 70 to 80ºF. It is drought tolerant with roots deeper than dry pea or lentil. Plant height ranges from 8 to 40 inches; the lowest seed pods are usually 4 to 6 inches from the ground. 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).

Uses

Kabuli type chickpeas (800 seeds/lb) are of high value and are used as an ingredient in salad bars in North America. The low value *desi* types (1500 seed/lb) are milled and used in dishes consumed mostly on the Indian continent, East Asia, and North Africa, which are potential market if production is expanded. Chickpeas are deficient in methionine and cystine.

Seeding date

Seeded early in spring when soil temperatures are above 40ºF or warmer. Experiments were conducted to determine the optimum seeding date for chickpeas in 2002 and 2003 in eastern Oregon. The results indicate that, in both years, the highest grain yields were obtained when seeding was done early in the spring at all sites except at Moro in 2003, where problems associated with plant stand were encountered in the first 3 seeding dates (Tables 1, 2). Despite the reduced plant population, the crop seeded early in mid-March still produced the highest yield. Based on these results, it is recommended to seed as early in March as practical to do in areas with similar climatic conditions to the sites used in this study. Plants seeded early can take advantage of a longer growing period under favorable temperatures and higher available soil moisture (Table 1). Seeding late reduces the growing period and exposes plants to high temperatures that can rise to more than 90ºF in June and July. Temperatures above 86ºF affect growth and heat stress can cause drop of buds, flowers, and young pods (Singh and Saxena, 1999). Based on our results, it is therefore recommended to plant either Dwelley or Sinoloa when seeding early and Sinaloa when seeding late or in locations that have limited water supply.

Table 1. Seeding date effects on grain yield (lbs/acre) of chickpea varieties at different sites in 2002

Seeding date	Milton Freewater		Pendleton		Moro	
	Dwelley	Sinaloa	Dwelley	Sinaloa	Dwelley	Sinaloa
Early April	1119a†	927a	400a	562a	819a	961a
Mid April	913b	886a	367b	476b	626b	775b
Late April	853b	914a	107c	425c	363c	594c

† means with the same letter within a column are not significantly different ($p<0.05$)

Table 2. Seeding date effects on grain yield (lbs/acre) of chickpea varieties at different sites in 2003

Seeding date	Pendleton		Moro	
	Dwelley	Sinaloa	Dwelley	Sinaloa
Mid March	1036a	1014a	823a	845a
Early April	794b	932b	591c	661c
Mid April	721c	728c	642b	686c
Late April	652d	744c	822a	758b

† means with the same letter within a column are not significantly different ($p<0.05$)

Seeding rate, depth and Row spacing

Seeding rates range from 80 lb/a for *desi* to 160 lb/a for *kabuli* lb/a; the recommendation is to germinate about 3plants/ft^2. Seed must be inoculated with appropriate bacteria to enhance N fixation. Results from our experiments indicate that increasing seeding rates generally increased grain yields at all the sites and in both years (Table 3, 4). The effect of seeding rate on grain yield was, however, influenced by seeding date. Increasing seeding rates significantly increased grain yield when seeding was done early in the spring. The magnitude of the increase in grain yield with increase in seeding rates was significantly reduced when seeding was done later in the season. The results at Moro, although confounded with plant population problems, still showed the same response. It is therefore recommended that higher seeding rates be used when planting is done early in the spring. Although high grain yields were produced at high seeding rates late in the season, the yield increase was small relative to early seeded crop and profitability may not justify the use of high seeding rate late in the season.

Optimum seeding rate was variety dependent. The optimum seeding rate for Dwelley was 3.0 seeds/ft^2. Increasing seeding rate to 4.5 seed/ft^2 did not result in significant yield increase and could be uneconomical. In contrast the optimum seeding rate for Sinoloa is 4.5 seeds/ft^2 in both years under both low and high soil moisture conditions. It is therefore recommended to seed Dwelley at 3.0 seeds/ft^2 and Sinaloa at 4.5 seeds/ft^2 if it is economical to do so.

Table 3. Seeding rate effects on grain yield (lbs/a) of chickpea varieties at different sites in 2002

Seeding rate (seeds/ft^2)	Milton Freewater		Pendleton		Moro	
	Dwelley	Sinaloa	Dwelley	Sinaloa	Dwelley	Sinaloa
1.5	806c†	786c	256b	388c	534b	640c
3.0	1071a	931b	313a	513b	633a	802b
4.5	1008b	1010a	306a	563c	641a	888a

† means with the same letter within a column are not significantly different ($p<0.05$)

Table 4. Seeding rate effects on grain yield (lbs/a) of chickpea varieties at different sites in 2003

Seeding rate (seeds/ft^2)	Pendleton		Moro	
	Dwelley	Sinaloa	Dwelley	Sinaloa
1.5	689c	680c	591b	659c
3.0	821b	872b	769a	745b
4.5	893a	1012a	799a	838a

† means with the same letter within a column are not significantly different ($p<0.05$)

Row spacing had no significant effect on grain yield for either variety. A row spacing of 6 inches in higher rainfall areas to 12 inches in lower rainfall areas are recommended. In other dry areas of the world, row spacing can be increased to 40 inches. Chickpea is planted at a seeding depth of 1 to 2 inches.

Fertilizer rates

Chickpea nutrient requirements are not well understood. With effective rhizobial inoculation, N application is generally not necessary unless soil tests indicate levels below 15 lb/a. In that case apply no more than 18 lb/a N. Do not apply with seed. Like other pulse crops, chickpea requires P, K, S, Mo, Mn, and Fe if deficient in soil and requires a pH of 6.0

Disease control

Ascochyta blight is the most serious disease and causes severe blight lesions. Cool, wet weather enhances infection and spread of disease. Unifoliate kabuli varieties are susceptible. Ascochyta blight can be controlled by seed treatment, spraying, resistant varieties, use certified disease-free seed, and rotating chickpeas once in 3 or 4 years.

Pythium and *Fusarium* fungi also attack germinating seed and can also be controlled by seed treatment. In 2002, plants that were seeded on April 3 were attacked by a combination of fungi and viruses more so than those planted in mid April and early May. Fungi isolated in Dr. Smiley's lab (CBARC, Pendleton) included *Fusarium solani* and *F. oxysporum*. Viruses isolated from the plants in Dr. Larsen's lab (USDA-ARS, Prosser, WA) included the bean leafroll and alfalfa mosaic viruses. *Fusarium solani* causes cortical root rot resulting in dark lesions and ultimately sunken areas of the root. This root rot damages plants slowly, causing them to become unthrifty and chlorotic but generally not killing them directly. Fusarium root rot can be easily seen by digging or pulling plants in most fields. *Fusarium oxysporum* is a pathogen that causes vascular discoloration and rapid wilting of entire plants. The vascular symptom can only be observed by slicing roots diagonally and looking for discoloration of vascular tissue without necessarily causing any discoloration of the center of the root, or of the cortical or epidermal tissues. The wilt caused early stunting of plants that were randomly scattered through the field. Affected plants became very yellow while still small in June, and they died by July. Despite the disease incidences, the highest grain yields were produced when seeding was done in early April. This is probably because there was more water available for plants seeded early in April than those seeded later. Plants seeded after the first week of April probably experienced both water and disease stresses. The disease incidences were very low in 2003.

Weeds

Chickpea is a poor weed competitor. Pre-emergence-pursuit and sulfentrazone (Spartan), prowl, post-emergence-pyridate for control of broadleaf weeds like kochia, pigweed, lambsquarters, and Russian thistle.

Flowering and Maturity

Desi chickpeas mature in about 115 days and *kabuli* chickpeas mature in about 125 days.
Maturity is delayed under cool summers; chickpea is indeterminate and continues to flower and set pods as long as climatic conditions are favorable

Harvesting

Chickpea is physiologically mature when seeds begin to change color inside uppermost pods. Direct combine or swath when pods are straw yellow; considered dry at 14% moisture. Seed color is most important; a yellowish-cream color is desirable. The seed should have less than 0.5% green seed content to receive US No. 1 grade. A dessicant (paraquat (Gramoxone Extra)) is normally used to dry down plants.

Yield potential

In general, grain yield range from 500-1500 lb/a; grain yield of 3500 lb/acre is possible. To determine grain yield potential under eastern Oregon conditions, a variety trial was conducted at Pendleton and Moro in the spring of 2002 and 2003. The varieties were seeded following wheat at Pendleton and following fallow at Moro. Grain yield varied from 300 to 1000 lbs/a (Table 5). In 2002, the *desi* chickpea, 'Myles', produced the highest yield, followed by 'CA99901604W' (Table 5). Bean yields from the other varieties were not significantly different from each other and were about 600 lbs/acre lower than the yield of 'Myles'. Despite being grown following wheat in a drought year, 'Myles' produced more than twice the yield of the other varieties. At Moro, Myles' produced the highest bean yields (Table 5). The yields of the rest of the varieties were not significantly different from each other and were about 200 to 300 lbs/acre lower than the yield of 'Myles'. The bean yields of the *kabuli* varieties were about 200 lbs/acre higher than at Pendleton, probably because they were grown on previously fallow land at Moro.

Table 5. Grain yield of chickpea varieties at CBARC Pendleton and Moro in 2002 and 2003

		Pendleton		Moro	
Variety	Type	2002	2003	2002	2003
		-----------------------------Lbs/a----------------------------			
Dwelley	*kabuli*	301.9	847.9	588.1	922.9
Sinaloa	*kabuli*	408.0	1097.8	642.1	759.6
Evans	*kabuli*	400.2	765.8	716.0	811.6
Myles	*desi*	1011.2	1059.9	880.3	839.7
Sanford	*kabuli*	387.7	863.3	647.8	829.7
Sierra	*kabuli*	400.8	867.2	656.4	745.3
CA99901604W	*kabuli*	539.4	693.7	702.6	729.7
$LSD_{0.05}$	-	223.2	257.7	195.4	207.1

To obtain both high grain yield and a high percentage of grade A beans in low and high yield environments, it is recommended that Sinaloa be grown. Dwelley should be grown only in high yield environments. If grain yield is the only important factor, then Myles should be grown in both low and high yield environments. Myles produces exceptionally high yields in low yield environments. There is a big market for *desi* type chickpeas in India, Pakistan and North Africa that need to be explored. Currently, the Canadians and Australians have a big share of this market.

High yielding lines are under development the USDA-ARS, Pullman under the leadership of Dr. Fred Muehlbauer. We cooperate with him in the evaluation of promising lines in the hope of finding lines suitable for eastern Oregon conditions. Grain yields of the lines we evaluated are shown in Table 6. Entry # 2, 10, 11 and 12 appear to be suitable for eastern Oregon conditions. More evaluations will be conducted.

Table 6. Grain yield and grain size of Western Regional Chickpeas lines (0399) evaluated at Moro and Pendleton in the Spring of 2003

Entry No.	Accession No	Grain yield (lb/a)		% grade A	
		Pendleton	Moro	Pendleton	Moro
1	CA188357	926.4	962.0	84.5	75.2
2	CA9783152C	1155.8	914.2	84.6	80.0
3	CA9783163C	989.1	939.5	86.3	84.3
4	CA9890169W	1190.9	866.2	87.0	82.8
5	CA9890233W	889.5	622.5	85.4	86.1
6	CA9890239W	970.7	711.5	90.0	86.6
7	CA9990I604C	1121.7	857.1	91.6	86.1
8	CA9990I861W	1043.2	986.2	81.1	81.0
9	CA9990I875W	759.3	768.0	91.3	89.7
10	CA9990B1514C	1115.2	1021.5	84.0	83.0
11	CA9990B1579C	1105.0	1063.4	85.8	82.7
12	CA9990B1895C	1056.0	1162.7	67.6	67.9
$LSD_{0.05}$	-	258.6	279.3	5.7	5.3

Rotational effects
Like most legumes. Chickpea fixes N that benefits the next crop, but, because of its deep root system, it dries up the soil profile and following wheat crop may experience drought stress particularly in years with less precipitation.

Marketing
Chickpea is contracted on an open market basis at about 18-23c/lb for grade “A” beans. Chickpea production must compete with wheat, which has lucrative government loan and crop insurance programs

Lentils (*Lens culinaris*)

Description

Lentil is an annual legume that 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*). Lentils grow to a height of up to 20 inches. In the Pacific Northwest, lentil plant height ranges from 8 to 13 inches; this height makes it difficult to harvest the crop.

Uses

An important food source and like chickpeas, have potential markets in the near east, northern Africa and the Indian subcontinent but deficient in methionine and cystine; green manure crop.

Seeding date

Winter lentils are seeded in the fall (October to November) and spring lentils are seeded early in spring when soil temperatures are above 50ºF from April 15 to May 15 to avoid seedling diseases. We conducted a seeding date experiment during the 2002-03 and 2003-04 crop-years at CBARC in Pendleton and Moro. In the 2002-03 crop-year, higher grain yields were produced when seeding was done in November compared to October in Pendleton (Table 7). Planting in

October reduced plant stands due to lack of soil moisture (crop dusted in). The opposite was true at Moro (Table 7). Grain yields were reduced when planting was done in November primarily due to grassy weeds. Herbicide (Assure®) application was delayed due to practical problems. WA8649090 produced the highest yields at both seeding dates at Pendleton. In Moro LC9440070 produced the highest yields at both seeding dates.

Table 7. Site and planting date effects on winter lentil grain yield at CBARC, 2002-03

		Pendleton	Moro
Planting date	Breeders lines	-----------------Grain yield (lbs/a) †-------------	
October 15	WA8649041	270.9	119.8
	WA8649090	608.4	583.4
	LC9440070	454.7	631.2
	LC999010	281.1	620.2
	mean	**403.8b**	**488.6a**
November 12	WA8649041	461.4	86.7
	WA8649090	891.9	237.6
	LC9440070	564.0	427.5
	LC999010	797.7	280.2
	mean	**678.8a**	**258.0b**
$LSD_{0.05‡}$	-	255.8	175.8

†means with same letters are not significantly different at 0.05 probability level.
‡LSD compares means of varieties

The experiment was repeated in the 2003-04 crop-year at both sites. Winter elite lentil lines, obtained from USDA-ARS, Pullman WA, were seeded at 20 seeds/ft in the fall of 2003 at two seeding dates; October 20th and November 11th at CBARC, Pendleton. The lentils were seeded as a re-crop following winter wheat. Grain yields of the elite lines are shown in Table 8. Harvest losses were not estimated. On average higher yields were produced when lentils were seeded in November than in October at Pendleton. At Moro, there were no significant differences in grain yields of lentils seeded in October and November. WA8649090 and LC999010 produced higher yields than the other lines at both seeding dates at Pendleton. WA869041 and LC999010 produced the highest yields at Moro. Broadleaf weeds were a major problem this past season and may have reduced grain yields. Better control of the broadleaf weeds is needed before winter lentils can be grown on a larger scale.

Seeding rate, depth and Row spacing

Lentil is planted at a seeding rate of 40 lb/a for small-seeded Spanish brown and red lentil types and 60 to 80 lb/a for large Brewer types. Aim for 15 to 20 plants/ft^2. Our data indicate that high yields were obtained at a seeding rate of 20 plants/ft^2.(Table 9, 10). It is recommended to seed at a row spacing of 6 inches in higher rainfall areas and at 12 inches in lower rainfall areas. The recommended seeding depth is 1 to 2 inches.

Table 8. Grain yield of Winter lentil lines at CBARC, Pendleton, OR, 2003-04

		Pendleton	Moro
Planting date	Breeders lines	-----------------Grain yield (lbs/a)	-------------
October 20	WA8649041	1076.3	1101.9
	WA8649090	1464.2	1017.3
	LC9440070	1151.7	1072.9
	LC999010	1477.1	1301.2
	mean	**1158.6a**	**1032.0a**
November 11	WA8649041	999.6	1211.3
	WA8649090	1873.0	1171.4
	LC9440070	1102.8	950.9
	LC999010	1771.6	1232.6
	mean	**1449.3b**	**1085.2a**
$LSD_{0.05}$	-	255	255

†means with same letters are not significantly different at 0.05 probability level.
‡LSD compares means of varieties

Table 9. Seeding rate effects on winter lentil grain yield at CBARC, 2002-03

	Pendleton			Moro		
Seeding rate	Grain yield (lb/a)†	Plant/ft^2†	Plant height (in) †	Grain yield (lb/a) †	Plant/ft^2†	Plant height (in) †
10 seeds/ft^2	434.8b	4.0b	13.1a	256.1b	3.7b	9.8a
20 seeds/ft^2	541.3a	6.4a	13.5a	373.3a	6.9a	9.9a

†means with same letters are not significantly different at 0.05 probability level.

Table 10. Seeding date and seeding rates effects on winter lentil grain yields, CBARC, 2003-04.

		Grain yield	
		Pendleton	Moro
Seeding date	Seeding rate	-----------------Lbs/a†----------------	
October 21	10	1024.9b	940.7c
	20	1292.3a	1123.3a
November 10	10	1464.8a	1028.8ac
	20	1436.7a	1141.6a

†means with same letters are not significantly different at 0.05 probability level.

Fertilizer rates

If available N is low, 30 to 40 lb/a should be applied to sustain plants until nodulation begins. Seed must be inoculated with appropriate Rhizobia bacteria to enhance N fixation. Like other pulse crops, lentil requires P, K, S, Mo, Mn, and Fe if deficient in soil. Lentils grow best in soil with a pH of 7.0.

Disease control

Lentils are attacked by the pea enation mosaic (virus) vectored from alternate hosts by the pea aphid. The root/wilt complex (*Pythium, Rhizoctonia, Sclerotium*, and *Fusarium* fungi) is the most important disease for lentils. *Ascochyta* blight is the most divastating disease of lentils worldwide (#1 limiting in Canada). Use Thiabendazole for control.

Avoid fababeans, fieldbeans, field pea, mustard, canola, rapeseed, soybean, sunflower, sugar beet, and potato in too close a rotation because these crops are susceptible to the same diseases.

Weeds

Lentils are poor weed competitors and require good weed control. Pre-emergence; pursuit (for broadleaf weeds control) along with triallate (Far Go) for wild oats should be applied. Metribuzin (Sensor) is applied for post-emergence weed control of grassy weeds. Post-emergence broadleaf weed control is a problem and a major obstacle to winter lentil production particularly during a wet spring.

Insects

Pea aphid is one of two primary pests of lentils (vector viruses and feed on plants). Lygus bug is the other pest. Apply dimethoate for control

Flowering and Maturity

Lentils bloom in about 60 days after emergence and mature in about 110 days.

Harvesting

Lentils are cut and swathed into windrows about one week before combining; some growers cut standing crop. Lentils are swathed when plants begin to turn yellow and the lower pods become brown to yellow-brown in color; considered dry at 14% moisture

Yield potential

Lentil grain yield evaluations were conducted from 2002 to 2004. In addition to the seeding date experiment discussed above, several spring lines and varieties were evaluated. Winter lentil lines were evaluated in the 2002-03 and 2003-04 crop-years at both Pendleton and Moro. Spring lentils were also evaluated at CBARC in Pendleton and Moro in the spring of 2003 and 2004. Moro and Pendleton received 8.82 and 15.42 inches of precipitation, respectively during the 2002-03 crop-year and 11.9 and 20 inches of precipitation, respectively in the

2003-04 crop-year. Winter lentils were seeded in October and spring lentils were seeded in March to May at a seeding rate of 20 seeds/ft^2. Data obtained are presented below (Table 11-15). Grain yields were generally low for both winter and spring lentils in the 2002-03 crop-year probably due to low precipitation. Seeding the spring lentils as late as May probably reduced the grain further. Grain yields of winter lentils ranged from 300 to 700 lbs/a (Table 11). Spring lentil yields ranged from 100 to 500 lbs/a (Table 13). Grain yields of both winter and spring lentils improved in the 2003-04 crop-year due to high precipitation and early seeding of spring lentils. Winter lentil yields ranged from 900 to 1800 lbs/a (Table 12, 14) and the spring lentil grain yields ranged from 1100 to 1600 lbs/a (Table 15). Of the spring lentil commercial varieties, Merrit produced the highest yield followed by Athena and Pardina. Skyline produced the lowest yields. High yields in 2004 were attributed to high and well distributed precipitation and timely seeding. Pendleton received about 20 inches of precipitation that was 4 inches higher than the 73-yr average. Winter types normally yield from 30 to 50% more than spring types but this was not the case in 2004 because of broadleaf weed problems in winter lentils.

Table 11. Site and variety effects on winter lentil grain yield at CBARC, 2002-03

	Pendleton			Moro		
Accession No.	Grain yield (lb/a) †	Plant/ft^2†	Plant height (in) †	Grain yield (lb/a) †	Plant/ft^2†	Plant height (in) †
WA8649041	323.9c	5.4a	13.7a	87.7c	4.6a	11.7a
WA8649090	700.4a	5.1a	13.0a	314.4b	5.43a	8.2d
LC9440070	456.1b	5.4a	13.2a	431.2a	5.9a	10.3b
LC9979010	471.7b	4.9a	13.2a	425.5a	5.6a	9.2c

†means with same letters are not significantly different at 0.05 probability level.

Table 12 . Site and variety effects on winter lentil grain yield at CBARC, 2003-04

	Pendleton			Moro		
Accession No.	Grain yield (lb/a) †	Plant/ft^2†	Plant height (in) †	Grain yield (lb/a) †	Plant/ft^2†	Plant height (in) †
WA8649041	1071.1c	17.3a	16.9a	1081.4a	23.3a	9.9a
WA8649090	1639.4a	14.5a	15.5a	1015.0a	21.4a	11.3a
LC9440070	1100.1c	13.1b	15.0b	986.0a	21.2a	11.0a
LC9979010	1405.1b	11.2b	16.6a	1151.9a	19.8a	10.3a

†means with same letters are not significantly different at 0.05 probability level.

Table 13 Grain yield and height of Western Regional Lentil lines (0398) evaluated in 2003

Entry No.	Accession No.	Pendleton		Moro	
		Grain yield (lb/a)	Plant height (in)	Grain yield (lb/a)	Plant height (in)
1	LC460197L	356.2	12.8	362.4	9.3
2	LC860359L	366.9	15.5	350.6	9.4
3	LC9960273L	247.2	15.13	244.8	9.6
4	LC99602075L	352.3	16.3	251.9	9.3
5	LC460266B	470.1	13.6	197.0	9.3
6	LC760209C	397.6	14.3	148.7	9.4
7	LC99602712T	318.3	10.6	117.6	9.6
8	LC99602724T	334.4	10.6	132.1	9.4
9	LC00600831E	347.7	12.3	212.9	9.5
10	LC00600854E	256.6	13.4	176.7	9.6
11	LC99602427P	429.8	10.6	120.7	9.6
12	LC00600812P	478.7	11.4	103.0	9.4

Table 14 Grain yield and height of Elite Winter Lentil lines evaluated in 2003-04 crop-year at CBARC, Pendleton, Oregon.

Entry #	Accession #	Grain yield (lb/a)	Plant height (in)
1	WA-041	1098.5	17.4
2	LC-062	1531.3	16.6
3	LC-079	961.9	15.3
4	LC-120	1642.6	15.9
5	LC-057	1124.9	14.1
6	LC-094	1426.8	15.6
7	LC-010	1825.9	14.8
8	LC-065	1657.5	15.8
$LSD_{0.05}$	-	508.6	1.7

Table 15. Grain yields of spring lentil varieties at Pendleton, OR, 2004

	Grain yield	
	------------------Lbs/a---------------	
Variety	Unadjusted	Adjusted (18%)
Regular	1426.33	1697.33
Skyline	1131.68	1346.70
Pardina	1428.90	1700.39
Eston	1362.92	1621.88
Athena	1445.85	1720.57
Merrit	1661.11	1976.71

Rotation effects

Lentils fix about 20lb N/a. A 3 to 4-year rotation away from lentil is best for disease reduction.

Production costs and Marketing

Lentils must compete with wheat, which has lucrative government loan programs and crop insurance programs. The cost of production averages $83/acre. Prices varied from 15c/lb to 35c/lb in early 1990s and dropped to 7c/lb in 1999. Price of lentils in WA depends on the Canadian crop and price structure.

Peas (*Pisum sativum*)

Description

Field pea is the most widely grown cool-season pulse. It is an annual cool-season legume (55 to 65ºF), growing 2 to 5 ft tall. 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. 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).

Uses

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). Biomass produced by winter peas ranged from 4000 to 5500 lbs/a (Table 16).

Seeding date

Peas are seeded in the fall (winter type) or in spring (spring type). They require 5, 2, or 1 week to emerge at soil temps of 40, 50 or 60, respectively. Because spring peas have been grown for quite some time, growers have determined optimum seeding dates for their respective climatic zones. Winter pea is a new alternative crop and agronomic work is required to determine its optimum growing conditions. To this end we conducted seeding date, seeding rate, and variety experiments in the 2003-03 and 2003-04 crop-years. To determine the optimum seeding date and seeding rate for winter peas two lines of winter pea were grown at the Columbia Basin Agricultural Research Center (CBARC) in Pendleton (45ºN, 118º West, elevation 1440 ft) and at Moro (45°N, 121°West, elevation 1835 ft). Soils at both stations are Walla Walla silt loams that are 4 to 6 feet deep. Moro received 8.82 and 11.2 inches of precipitation in the 2003-03 and 2003-04 crop-years, respectively and Pendleton received 15.4 and 20.2 inches of precipitation in the 2003-03 and 2003-04 crop-years, respectively. The peas were grown at two planting dates and two seeding rates. Data obtained are presented below (Table 17, 18). Unfortunately the winter peas at Pendleton could not be harvested because peas from different plots had grown so big and into each other, we could not distinguish the plots.

There were significant interactions between site, planting date and variety on grain yield at both sites in both crop-years (Table 17, 18). At Pendleton, grain yield of PS9530726 significantly increased when seeded in November while grain yield of PS9430706 was not influenced by seeding date in the 2002-03 crop-year (Table 17). The yield of PS9430706 was significantly higher than the yield of PS9530726 for both seeding dates. At Moro, there were no significant differences between the varieties for each seeding date and between the seeding dates (Table 17). The following results were obtained at Moro in the 2003-04 crop-year (Table 18). Grain yields were, however, much higher during the 2003-04 crop-year than yields in the previous crop-year (Table 18). Both varieties appear to be adapted to eastern Oregon conditions. Further work is required.

Table 16. Biomass and grain yield of winter peas and winter lentils at CBARC Pendleton and Moro, 2001-2002 crop year.

Winter Peas†			Winter Lentils†		
Entry	Biomass (lbs/a)	Grain yield (lb/a)	Entry	Biomass yield (lb/a)	Grain yield (lb/a)
PS9430706	5684.3a	1415.6a	WA8649041	2656.7a	722.02b
PS9430726	4640.8b	1388.9a	LC9440070	2170.4b	606.43b
PS9530645	4747.9b	532.6b	WA8649090	2489.9a	899.86a

† means with similar letters are not significantly different at the 0.05 probability level

Table 17. Grain yield of Winter Pea lines at CBARC, Pendleton and Moro, OR, 2002-03

		Pendleton	Moro
Planting date	Breeders lines	-----------------Grain yield (lbs/a) †-------------	
October 15-16	PS9530726	1241.4	1140.2
	PS9430706	2050.8	1015.2
		1497.6b	**1030.1a**
November 11-14	PS9530726	1623.7	896.5
	PS9430706	1982.5	1174.2
		1773.4a	**899.0a**
$LSD_{0.05}$		319.5	461.4

†means with same letters are not significantly different at 0.05 probability level. LSD compares means of varieties

Table 18. Grain yield of Winter Pea lines at CBARC, Moro, OR, 2002-03

Planting date	Breeders lines	Grain yield (lb/a) †
October 15-16	PS9530726	1787.7
	PS9430706	1930.4
		1859.1a
November 11-14	PS9530726	1879.3
	PS9430706	1606.1
		1742.2a
$LSD_{0.05}$		425.3

†means with same letters are not significantly different at 0.05 probability level. LSD compares means of varieties

Seeding rate, depth and Row spacing

Peas are normally seeded at 7 seeds/ft2 (1400 to 3500 seeds/lb) depending on variety so rates vary from 80 to 200lb/a; for grain/pea mixtures, peas should be 60 to 66% of the mixture. We conducted a seeding rate experiment at CBARC Pendleton and Moro in the 2002-03 and 2003-04 crop-years. Peas were seeded at either 5 or 7 seeds/ft^2. On average, there was no significant difference in grain yield between the two seeding rates in the 2002-03 crop-year (Table 19). However, yield of both varieties increased with increase in seeding rate. PS9430706 consistently produced higher yields than PS9530726 and this was significantly so at Pendleton. In the 2003-04 crop-year increasing seeding rates significantly increased the average grain yield at Moro (Table 20). There was no data obtained from Pendleton. Based on these results peas should be seeded at

7 seeds/ft^2. The effect of higher seeding rates than 7 seeds/ft^2 was not investigated.

Peas are normally seeded in rows 6 to 7 inches apart at a depth of about 2.5 inches; hoe drills are preferred.

Table 19. Seeding rate effects on grain yield of Winter Pea lines at CBARC, Pendleton and Moro, OR, 2002-03

		Pendleton	Moro
Seeding rate (seeds/ft^2)	Breeders lines	----------Grain yield (lbs/a) †------	
5	PS9530726	1242.8	848.4
	PS9430706	1866.2	896.9
		1554.5a	**872.6a**
7	PS9530726	1432.5	1018.4
	PS9430706	2000.6	1094.7
		1716.5a	**1056.5a**
$LSD_{0.05}$		338.12	292.5

†means with same letters are not significantly different at 0.05 probability level. LSD compares means of varieties

Table 20. Seeding rate effects on grain yield of Winter Pea lines at CBARC, Moro, OR, 2002-03

Seeding rate (seeds/ft^2)	Breeders lines	Grain yield (lb/a) †
5	PS9530726	1705.7
	PS9430706	1739.6
		1722.7b
7	PS9530726	1833.0
	PS9430706	1768.3
		1800.6a
$LSD_{0.05}$		302.5

†means with same letters are not significantly different at 0.05 probability level. LSD compares means of varieties

Fertilizer rates

Like all legumes, peas should be inoculated prior to planting; apply 20 to 40 lb/a N at seeding if soil test is <20 lbs N/acre. P, K rates for peas are similar to small grains. Peas require a pH of 5.9 to 6.5 but can grow in soils with up to pH 7.5.

Disease control

Seed treatment with Thirum®, Captan® or Apron® prevent diseases. Major diseases include seed rot, root rot, and blights of stems, leaves ,and seeds caused by *Fusarium solani, Pythium spp, Rhizoctonia solani.* A 4 year rotation is recommended. Peas are affected by *Aschocyta* blight, which causes purplish-black streaks or lesions on leaves, stems, or pods. Peas are also susceptible to Pea mosaic virus which is vectored by the pea aphid. Septoria blight, bacterial blight, powdery mildew and downy mildew also affect peas.

Weeds
The latest varieties of winter pea grow so much biomass that weeds are smothered. Weed control is critical in early spring when peas are very small. As temperatures increase, winter peas grow very rapidly and smother most weeds. Herbicides that are commonly used in peas are Pursuit®, Sencor®, Treflan® and Sonalan®

Insects
Pea leaf weevil and Pea aphid are common insects that infest peas.

Flowering and Maturity
Spring peas flower in about 60 days and mature in about 90 to 110 days. High temperatures during flowering may cause flowers to blast. The crop is at physiological maturity when all pods have turned yellow or tan.

Harvesting
Peas are directly combined when seed moisture <20% (ideally 16%) or swathed before they are too dry. Lodging is common in peas; so swath or combine at a 90-degree angle to direction of lodging. Use very low cylinder speeds (350 to 600 rpm) to reduce splitting, concave settings at 0.6in, lowered or removed if crop is very dry.

Yield potential
The yield potential of peas varies greatly depending on site and environmental factors. Yields range from 900 to 3500 lbs/a. We evaluated 12 lines of spring peas at CBARC in Pendleton and at Moro and six lines of winter peas at CBARC in Pendleton in the 2002-03 crop-year. We also evaluated commercial varieties in 2001-02, 2002-03 and 2003-04 crop-years at Pendleton. Soils at both stations are Walla Walla silt loams that are 4 to 6 feet deep. Winter peas and spring peas were planted in October and March, respectively, at a seeding rate of 7 seeds/ft^2. The crops were grown after winter wheat at Pendleton and after fallow at Moro. For both crops, the plant stand was low due to poor germination and emergence. Seedbed conditions were not idea due to too much straw from the previous wheat crop. However, despite the low plant stands, both winter and spring peas produced higher grain yields than in 2003. Grain yields of the winter pea varieties ranged from 1900 to 3000 lbs/a (Table 21). Spring peas produced about 700 to 1100 lbs/a at Pendleton and 300 to 600 lbs/a at Moro (Table 22). Winter pea lines yield 1200 to 1900 lb/a more than spring types.

The effect of precipitation is clearly demonstrated in Table 23. Grain yields of commercial spring varieties increased by 3 to 4 times in 2003-04 crop-year compared to yields in the previous years. Precipitation at Pendleton was 20 inches in 2003-04 crop-year compared to 15 inches and 13 inches in 2002-03 and 2001-02 crop-years, respectively. Grain yields ranging from 2700 to 3200 lbs/a were obtained in the 2003-04 crop-year. The variety ‘Universal’ appears to yield well under both dry and wet years but the yield was not significantly different from Badminton and Mozart under dry and wet conditions. We therefore recommend all the three varieties to growers.

Table 21 Grain yield and height of Elite Winter Pea lines evaluated in 2003-04 crop-year at CBARC, Pendleton, Oregon.

Entry #	Accession #	Grain yield (lb/a)	Plant height (in)
1	PS-010	2628.0	52.0
2	PS-431	1902.4	42.8
3	PS-448	2367.1	47.3
4	PS-358	2859.3	33.5
5	PS-011	2459.7	33.1
6	PS-009	3136.8	45.8
$LSD_{0.05}$	-	1183	11.0

Table 22 Grain yield and height of Western Regional Dry Pea lines evaluated in 2002-03

Entry No.	Accession No.	Pendleton		Moro	
		Grain yield (lb/a)	Plant height (in)	Grain yield (lb/a)	Plant height (in)
1	PS610152	1162.8	9.6	475.1	8.1
2	PS710048	1027.3	9.8	482.6	8.1
3	PS810162	735.5	9.8	370.4	7.5
4	PS810191	1122.0	10.4	431.0	8.3
5	PS810240	1243.8	9.4	718.8	7.0
6	PS9910346	1001.7	9.8	574.1	7.9
7	PS9910592	977.0	9.9	431.0	8.3
8	PS710909	801.7	9.9	311.9	8.1
9	PS99101364	793.6	10.4	287.2	8.4
10	PS99101381	835.2	10.0	308.3	7.9
11	PS9910140	1066.4	9.9	646.8	7.9
12	PS9910188	1319.0	10.3	679.3	7.5
$LSD_{0.05}$		320.5	0.8	173.4	0.8

*Similar letters to the right of the numbers indicate that the means are not significantly different ($P<0.05$)

Table 23. Grain yield and height of commercial spring pea varieties in 2001-02, 2002-03 and 2003-04 crop-years at CBARC, Pendleton, Oregon.

	2001-02		2002-03		2003-04	
Variety	Grain yield (lb/a)	Plant height (in)	Grain yield (lb/a)	Plant height (in)	Grain yield (lb/a)	Plant height (in)
Jasmine	613.5	15.8	-	-	-	-
Badminton	779.7	12.3	797.2	13	2736.1	33.0
Midas	670.7	14.3	-	-	-	-
Eiffel	779.2	16.5	-	-	-	-
Universal	858.0	14.3	767.4	17.8	3267.5	42.8
Mozart	-	-	786.3	11.9	2945.5	37.0
$LSD_{0.05}$	143.5	3.2	166.2		553.6	3.8

Rotation effects

Peas can be grown in a mixture with barley, oat, triticale or wheat. Peas are an excellent N fixing crop (30lb/a/yr) and have great potential as a green manure crop instead of fallow. Peas can return more than 80 lbs N/a to soil if killed in mid-season. The response of pea to moisture is similar to wheat.

Production costs and Marketing

Price ranges from $5.50 to >$11.00/100 wt that can result in potential gross returns of $82.50 to $165.00/1500 lb/a

Faba beans. (*Vicia faba*)

Description

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).

Uses

Faba bean does not contain any toxins and is used for both human (higher feed value than other legumes); second ranking food legume in Europe. Faba bean can be fed to all types of livestock; have 25% protein and higher in energy than soybean; can be used to replace soybean as protein supplement. The bean makes high quality silage; it is swathed when lower pods begin to blacken.

Seeding date

Faba bean is very cold hardy but cannot take excessive heat during flowering. It has shallow roots, so it should be planted very early. Seed faba beans early in March or April. Yields are reduced as seeding is delayed into May. Seedlings are frost tolerant.

Seeding rate, depth and Row spacing
Faba beans can be seeded in rows 7 to 14 inches apart using lima bean planters at 87 to 136 lb/a. Seed at a depth of 2.5 to 4.0 inches to avoid surface drying out (seed is hard and takes longer to imbibe).

Fertilizer rates
Faba beans should be inoculated prior to planting; apply15 to 35 lb/a N at seeding if soil test is less than 15 lbs N/a. Faba beans require soil with medium to high range of P, K; similar requirement to canning peas. A pH of 6.0 is desirable.

Disease control
Faba bean is susceptible to a number of diseases. Chocolate spot, rust, black root rot, stem rots, root rots and damping off, downy mildew, ascochyta blight, foot rots, bean yellow mosaic, bean true mosaic, and bean leaf roll virus all affect faba beans. Disease resistant varieties are needed before big acreages can be planted.

Weeds
Faba beans are poor competitors with weeds. Herbicides that are normally used to control weeds in Faba beans are similar to pea herbicides. They include Pursuit®, Sencor®, Treflan® and Sonalan®

Insects
Ground nut aphid, black bean aphid, pea aphid, pea thrip, cowpea bean bettle seed weevils, bean weevil, leaf hoppers, gray blister beetles, black aphids, and nematodes attack faba beans.

Flowering and Maturity
Faba beans flower in about 60 days and mature in about 80 to 220 days. High temperatures during flowering may cause flowers to blast. Lower leaves darken and drop, pods turn black and dry progressively up the stem as the crop matures. The beans tend to shatter if left standing until maturity.

Harvesting
Swath when lowest two banches of pods begin blackening or when most seed easily detaches from hilum (35 to 45% moisture). The beans need a fairly long drying period in the swath; dry to 16%. Use low cylinder speeds of 300 to 500 rpm during combine harvesting.

Yield potential
Faba bean grain yields vary from 500 to 1500 lb/a, >2000 up to 4000 lb/a possible (with 27 to 32% crude protein) under ideal conditions. Grain yield obtained from our trials at CBARC Pendleton were very low and ranged from 8 to 11 lbs/a. Low yields were attributed to poor stands and disease. Results indicate

that the varieties evaluated, most from Canada, were not adapted to eastern Oregon conditions. Breeding work is needed to develop faba bean varieties adapted to eastern Oregon conditions.

Up to 4370 lb/a dry forage with 10.5% protein can be produced under ideal conditions.

Rotation effects

Faba bean should be grown once in every 4 years in the same field. It has the same diseases as rapeseed, sunflower, specialty crops. Faba bean is an excellent N fixing crop and can leave as much as 150 lb/a for subsequent crops.

Production costs and Marketing

Faba bean markets in US are negligible. About 60% of faba beans are produced in China

Table 24. Faba bean grain yield at CBARC, Pendleton, 2002

Variety	Grain yield (lbs/a)
Melody	10.7
Devine	16.3
Cresta	10.5
CDC Fatima	11.6
CDC Blitz	11.0
Quattro	10.8
Compass	8.8
Scirocco	10.7
$LSD_{0.05}$	6.8

Linola/Flax. (*Linum usitatissimum*)

Description

Flax (*Linum usitatissimum* L.) is a self-pollinating, annual plant with one main stem; branches at the base under low plant density or when soil N is high (similar to wheat tillering). The plant grows to a height of 16 to 36 inches; short branched taproot that can extend to 49 inches with side braches up to 12 inches long. Flax 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 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.

Uses

Flax seed produces oil rich in alpha-linolenic acid, a polyunsaturated fatty acid that makes oil highly susceptible to oxidation. This imparts a drying property to the oil and gives it its traditional industrial use in the manufacture of biodegradable paints, varnishes, inks, and linoleum; seeds are brown to dark brown; linseed meal can be used in dairy rations and commercial fish farms.

Linola is flax bred for edible oil (low in linolenic acid, high in linoleic acid) similar in composition to sunflower, safflower, and corn; meal after oil extraction is valuable of protein and energy for animal feeding; seeds are golden yellow.

Flax produces fiber in stems that is used in making fine linens for clothing, draperies, toweling, matting, rugs, twines, canvas, bags, quality papers (currency notes, cigarette papers, fine bond papers) and furniture. Medium fibers are used for canvas and geo-textiles, while short fibers are used for paper and sacking.

Seeding date
Flax can be established under both summer fallow and direct-seeding conditions. Planting should be done after the last killing frosts in the spring. Seedlings can tolerate temperatures as low as 30ºF.

Seeding rate, depth and Row spacing
Flax is usually seeded at about 30 to 40 lb/a; aim at 30 to 50 plants/ft2. Stands of less than 30 plants/ft2 reduce yields. Avoid high seeding rate to reduce lodging; plants compensate for thin stands by branching. Plant at 1 to 1.5 in (2 in drier soil) deep
Can be planted by all conventional seeding equipment; if crusting occurs, light harrow.

Fertilizer rates
Requires 2.7 lb N/bu of grain produced; fertilizer requirements are similar to wheat. Flax has less requirements for P and K than cereals but need more sulfur.

Disease control
Flax is susceptible to *Fusarium* wilt, *Rhizoctonia* root rot, and seedling blight. Disease can be minimized by rotating fields and seed treatment. Flux rust can also affect flax yields

Weeds
Flax is a poor competitor with weeds. Apply Buctril® for broadleaf weed control and Roundup® for pre-harvest weed management. Flax produce hard to kill volunteers.

Insects
Aphids, Bedrtha armyworms, cutworms and grasshoppers can be a problem for linola. Flax bollworm only attacks flax. Insecticides can be used to control the insects if that is economical to do so.

Flowering and Maturity
Flax flowers in 45 to 60 days; the flowering period is about 16 to 26 days and the crop matures in 30 to 40 days. The plant has ability to shut down flowering under high temperature and resume when conditions are right. Seeds are produced in a boll. When ripe, bolls open at the tip and 5 segments separate slightly along the margin. Plants fully mature when 75% of bolls are brown and completely mature when 90% of bolls are brown. Seed should be stored at about 10.5% moisture.

Harvesting
Flax can be combined directly or swathed; swathing preferred as this assures uniform drying of the crop. A desiccant can also be applied when 75% of bolls are brown and then direct combine immediately. Flax straw is baled and fiber processed into paper products (up to 1000 lb/a of fiber); chop straw before

spreading; do not graze green straw-it contains high levels of prussic acid. Mature straw can be fed to cattle.

Yield potential
Seeds grow in a boll or capsule; each ball has 5 segments; each segment produces 2 seeds (10 seeds-6 to 8 common). Flax generally produces more yield than linola; average yield is 1000 lb/a (20 bu/a). Flax and linola, together with other alternative crops, were evaluated for suitability to eastern Oregon conditions at CBARC Pendleton and Moro Centers from 2002 to 2004. Grain yields of linola varied from 100 to 350 lbs/a and grain yield of flax ranged from 100 to 400 lbs/a (Fig 1-5). Grain yields were higher in Pendleton than at Moro. Grain yields can be improved if more agronomic work is done to determine the optimum seeding rates, row spacing, and fertilizer rates for flax grown under eastern Oregon Conditions.

Rotation effects
Flax uses less water and leaves enough water for other crops in rotation. Linola and flax must be grown 5 years apart to avoid contamination. Grain yields are reduced when following canola or mustard probably due to toxins from residue.

Production costs and Marketing
Flax is produced in Canada, Argentina, China, India, and former Soviet Union Republics. North Dakota is the only state growing significant amounts of flax (536,000 acres in 2000). Flax sells at about 5 to 12c/cwt; there is a worldwide demand of 2.2 million metric tons annually. Seed and fertilizer costs are lower than for wheat (need 31.3 bushel/a to cover costs for wheat production). Linola marketed under contract; government loan program is available for flax, but not for linola.

Safflower (*Carthamus tinctorious*)

Description

Safflower (*Carthamus tinctorius* L.) is an annual domesticated broadleaf thistle with a strong central branch stem, a number of branches and a large tap root system to a depth of 10ft; branches have 1 to 5 flower heads with 15 to 20 seeds/head; grows to 12 to 36 in; braches 18 to 30 in long. It is an oilseed crop adapted to cereal grain areas of the western Great Plains.

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).

Uses

Safflower is a versatile crop; it can be grown for edible oil, meal, or whole seed for dairy cattle, birdseed, and oil for industrial uses like producing non-yellowing drying paints, alkyd resins in enamels, caulks, and putties. Because of its high linoleic acid content, safflower commands a premium price among edible oils, and is competitive with canola and olive oil.

Seeding date

Safflower is seeded in April or early May (when temperatures are above 45ºF soil temperature). Seedlings emerge in 1 to 3 weeks and early development is very slow; spends 2 to 3 weeks in rosette stage and at this stage will tolerate temperatures as low as 20ºF but susceptible to frost injury from stem elongation to maturity.

Seeding rate, depth and Row spacing

The crop is seeded in 6- to 20-in rows at 20 lb/a (130,000 plants/a), narrow rows are better for weed competition. A 20 lb/a seeding rate in 12, 10, 8, and 6-in rows would require 6, 5, 4, and 3 seeds/linear foot row. Seed at a depth of 1in or 1.5 in (not more than 2 in); susceptible to soil crusting

Fertilizer rates
Safflower require 100 lb/a N for 2000 lb/a yield; apply P, K as required by soil tests; tolerates saline soils like barley

Disease control
Diseases that affect safflower include Alternaria blight spotting disease, Sclerotinia head rot, damping off, rusts, white mold.

Weeds
Safflower is a poor competitor with weeds early in the growth cycle; the crop takes long to germinate and spends 3 to 4 weeks in the rosette stage; cereal volunteer can be problematic. Trifluralin applied pre-plant and incorporated will control some grass and broadleaf weeds

Insects
Wireworms, cutworms, and lygus bugs infest safflower

Flowering and Maturity
Safflower requires 2200 growing heat units and 120 frost-free days

Harvesting
The crop is harvested directly when crop is at 9 to 13% moisture, about one month after flowering and when most leaves have turned brown; seeds should rub freely from the heads. Bird damage may be a problem

Yield potential
Grain yields range from 1000 to 1600 lb/a (>2000 lb/a possible with 15 in precipitation). In eastern Oregon, safflower grain yields of 544 to 1892 have been obtained (Rasmussen and Smiley 1994). Safflower, together with other alternative crops, was evaluated for suitability to eastern Oregon conditions at CBARC Pendleton and Moro Centers from 2002 to 2004. Grain yields of safflower varied from 500 to 1100 lbs/a (Fig 1-5). Appropriate agronomic practices (seeding rates, row spacing, fertilizer, and varieties) for safflower should be determined for eastern Oregon conditions. Seed oil content is 30 to 45%. White seeded varieties produce oil high in linoleic acid (polyunsaturated fats). The bird seed market prefers white seeded varieties; striped seed varieties produce high oleic acid (preferred by Japanese)

Rotation effects
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. Safflower has a dense root structure that improves tilth and porosity (break up pan in no-till systems). The crop, however, dries up soil for next crop; therefore plant after fallow or follow with

spring cereals. Do not follow safflower with sunflowers, peas, lentils, and canola because they suffer from same diseases.

Production costs and Marketing

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. At $107 to $120/a, growers needs a price of $0.10/lb and yield of 1200 lbs/a to break even. Contracts are necessary to ensure a market before planting. Current oilseed markets and crushing plants are in North Dakota, Montana, and California. The predominant market is for varieties producing high oleic acid and very low unsaturated fatty acids; high oleic acid prevents coronary artery disease. Safflower has higher oleic acid and monounsaturates than olive oil. Oil of this type is used as a heat stable cooking oil to fry French fries, chips, and other snack items

Sunflower (*Helianthus annus*)

Description
Sunflower is the world's second most important source of edible oil. Originated in North America; warm season annual broadleaf crop and insensitive to day length. Sunflower has a strong tap root and prolific lateral roots. Its extensive root system can grow as deep as 6 ft. There are oil and confectionary types. The crop is drought and frost tolerant except during the bloom period. 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 day length, 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).

Uses
Sunflower is grown for 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*).Oil and confectionary; oil types are smaller and black and also used as bird feed.

Seeding date
Sunflower is planted when temperatures are above 46ºF (March to May); minimum temperatures for growth are 70 to 78ºF but 61 to 91ºF show little effect on productivity.

Seeding rate, depth and Row spacing
Sunflower can be planted with corn or beet planter in 15- to 36-in rows and at a depth of 1.5 inches or into moisture. The target population is 20,000 plants/acre

(there are 2500 to 3000 seeds/lb for confectionary types and 5000 to 10000 seeds/lb for oil types). Sunflower is capable of producing same yield over a wide range of plant densities; plants adjust head diameter, seed number/plant, and seed size.

Fertilizer rates
Test soil for N down to 4ft; sunflower requires 5 lb of available N/100 lb of seed yield; apply P and K according to soil tests.

Disease control
Downy mildew is a problem and occasionally some rusts

Weeds
During early vegetative stages, plants are very sensitive to competition for moisture. Treflan, Solanan, and Prowl are registered herbicides for sunflowers.

Insects
Few insects damage sunflowers. These include red seed weevil, gray seed weevil, head moth, and banded moth. Birds are predatory to sunflowers

Flowering and Maturity
Matures in 90 to 110 days when bracts are dry, brown or have dropped (seeds at 35% moisture).

Harvesting
Harvest at 10 to 18% moisture; store at 10% moisture or below; oil types deteriorate rapidly after shelling

Yield potential
Sunflowers can produce seed yield of 2000 to 3000 lb/a and oil yield of 30 to 50%. 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 to 7ft 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. Sunflower, together with other alternative crops, was evaluated for suitability to eastern Oregon conditions at CBARC Pendleton and Moro Centers from 2002 to 2004. Grain yields of sunflower varied from 300 to 800 lbs/a at Pendleton and from 80 to 500 lbs/a at Moro (Fig 1-5). Yields were low due to substantial bird damage; potential yields are higher than the reported yields. Furthermore, appropriate agronomic practices (seeding rates, row spacing, fertilizer, and varieties) for sunflower should be determined for eastern Oregon conditions. Commercial sunflower hybrids can be grown in the warmer dryland areas of northern Idaho (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).

Rotation effects

Sunflower may dry up the sub soil; so follow sunflower by spring wheat or spring barley

Production costs and Marketing

Sunflower is primarily produced in N and S Dakota, Colorado, Kansas, Minnesota, Nebraska, and Texas and 80% of oil is exported. There is also a big market for in-shell sunflower seed for use in place of chewing tobacco. Confectionary sunflowers are used for cooking, baking, and salads and oil type sunflowers are used for bird seed. There is a commercial bird seed processor in Spokane. Oil types also sold for dairy rations; a lactating cow can use about 4 lbs/day of oil type sunflowers. Most dairy farms use cottonseed to provide the needed fat (costly transportation). Sunflowers have a loan rate of $9.30/cwt; obtain contract before planting. North Dakota, Minnesota, and Kansas have oilseed crushing plants for sunflowers (too far for Oregon growers). We need about 600,000 lbs to justify a crusher. NuSun is a new hybrid sunflower with oil that does not breakdown under consistent heat; preferred by Snack-food producers. Price of oil-type seeds is $10/cwt, that of confection-type seeds is $13 to $14/cwt. Cost of production and return over variable costs for sunflower in similar to that for small grains

Mustard. (*Brassica* spp.)

Description

Mustard is a cool-season, annual broadleaf crop. Varieties of yellow mustard usually mature in 80 to 85 days whereas brown and oriental types require 90 to 95 days. Mustard 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. Cultivars of mustard evaluated in the PNW (northern Idaho) were developed in Canada and North Dakota for areas with greater summer rainfall (Oplinger et al., 1991).

Uses

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.

Seeding date

Mustard is seeded when soil temperatures are between 40 and 45ºF; in March in eastern Oregon.

Seeding rate, depth and Row spacing

Mustard should be seeded at 5 to 14 lbs/a depending on seed size (yellow mustard has about 100,000 seeds/lb and brown and oriental mustards have 200,000 seeds/lb). Research results in eastern Oregon have consistently indicated that adequate stands were achieved at 7 lb/acre (Wysocki, et al., 1997). When seeding, the seed should be placed 0.5 to 1 inches deep into moist soil. Mustard is usually seeded on 6- to 7- in row spacings for the crop to be competitive with weeds. However, row spacings up to 12 inches wide can be used.

Fertilizer rates
Fertilizer requirements of mustard are similar to rape or canola requirements. Optimum yields are obtained at about 100 to 120 lbs N/acre. A maintenance application of about 20 lb P_2O_5 and 10 lbs S/acre is recommended. Low rates of phosphorus fertilizer (<100 lb/acre 16-20-0-14) can be mixed with seed at planting (Wysocki et al., 1997).

Disease control
Mustard is attacked by Sclerotinia stalk rot (white mold), downy mildew, white rust, leaf spots, and mosaic virus. In eastern Oregon, Sclerotinia stalk rot is the only disease that has attacked mustard (Wysocki et al., 1997). Crops with similar diseases to mustard include sunflower, rapeseed, canola, safflower, soybeans, crambe, and dry beans; therefore do not rotate mustard with these crops.

Weeds
Mustard is a poor competitor with weeds early in the season; ensure the establishment of a uniform and vigorous crop to help control weeds.

Insects
Based on work conducted by Wysocki et al., (1997), insects have not caused serious problems on yellow mustard in this region. However, growers should be on the look out for flea beetles and diamondback moth caterpillars. Activity of these insects increases under hot and sunny conditions. Aphids were also observed on mustard in our 2003 experiments.

Flowering and Maturity
Flowering begins about 5 weeks after emergence and flowering can continue for a long period with adequate water supply; high yields are obtained when flowering is long. Yellow mustard matures in 80 to 85 days.

Harvesting
Yellow mustard does not shatter and can be direct combined if the crop is uniformly ripe and free of green weeds. Cylinder speeds should be set at 600 RPM to ensure complete threshing of seed (Wysocki et al., 1997). The crop should be swathed if weedy or uneven in maturity. Swathing is preferred and should be done when 60 to 70% of seed has turned yellow green. Oriental and brown varieties shatter and should always be swathed.

Yield potential
Experimental yields in the PNW range from 560 to 2,200 lbs/acre (Shelton 1999, Schillinger et al., 2002, Wysocki et al., 1997; Brown and Wysocki 2003). Mustard, together with other alternative crops, was evaluated for suitability to eastern Oregon conditions at CBARC Pendleton and Moro Centers from 2002 to 2004. Grain yields of mustard varied from 100 to 900 lbs/a at Pendleton and from 100 to 600 lbs/a at Moro (Fig 1-5).

Rotation effects

Mustard, like rapeseed, suppresses diseases in cereal-based rotations (Vaughn 1999). Sunflower, rapeseed, canola, safflower, soybeans, crambe, and dry beans should not be rotated with mustard because they have similar diseases.

Production costs and Marketing

Small contract acreages of spring mustard are grown in the region for the condiment industry. Production costs of mustard are lower due to lower seed and pesticide costs than production costs of wheat

Buckwheat (*Fagopyrum esculentum/sagittatum* Moench)

Description

Buckwheat is a short season, indeterminate broadleaf cereal crop grown for flour that originated in China. It grows under a wide range of soil conditions but it is sensitive to spring and fall frosts, high temperatures, wind and drought especially at bloom. Flowers are self incompatible and requires cross pollination through wind and insects. Buckwheat has small tap root and underground portion of plant makes up about 3% of total biomass of the crop (uses only the top 2 to 3 ft of soil profile). Buckwheat emerges and produces a canopy very quickly.

Uses

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) and 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).

Seeding date

Planted when danger of frost is past; germinates at soil temperatures of 45 to 105ºF. Planting is timed so that plants bloom and set seed when hot, dry weather is over; emerges in 3 to 5 days. Buckwheat evaluated in our studies was seeded at the end of April and in May.

Seeding rate, depth and Row spacing

Plant 1 to 2 inches deep at 50 lb/a under dryland conditions and at 70lb/a under irrigation. Aim to seed 16 seeds/ft^2. We have used row spacings of 6 inches.

Fertilizer rates
Buckwheat requires 45 to 50 lb N; lodges in soils high in N. Add P if soil tests are below 20 ppm; buckwheat is efficient in extracting P of low availability from soil. Other nutrient requirements are similar to cereal grains. Buckwheat does not grow well in heavy, wet soils or in soils containing high levels of limestone. The crop tolerates high acidity.

Disease control
Diseases are not a problem in buckwheat. *Rhizoctonia* root rot and *Ramilaria* leaf spot sometimes affects buckwheat.

Weeds
No identified weed pests in the PNW. Buckwheat in uniform stands will compete with weeds.

Insects
Buckwheat has no identified insect pests in the PNW. Wireworms and aphids may attack buckwheat, but cause little damage. Japanese beetles are a threat and feed on flowers.

Flowering and Maturity
Buckwheat matures in 75 to 80 days after planting. Seeds are mature when they have turned brown or black and the plants have lost most of their leaves.

Harvesting
Buckwheat requires swathing when about 70% of seeds are black or brown and a minimum of 13% moisture (preferred 15 to 16%) is required for harvest; anything less will result in unacceptably high shatter loss. Use cylinder speeds of about 650 RPM.

Yield potential
Grain yields of 900 to 1100 lb/a for dryland and from 2200 to 3400 lb/a under irrigation have been obtained. Buckwheat, together with other alternative crops, was evaluated for suitability to eastern Oregon conditions at CBARC Pendleton and Moro Centers from 2002 to 2004. Grain yields of buckwheat were < 100 lbs/a at both Pendleton and at Moro (Fig 1-5). The crop was susceptible to drought and high temperature stress during flowering and grain filling. Considerable grain was also lost through shattering when harvesting was delayed. For these reasons, we recommend that buckwheat should be used only as a cover crop under our conditions.

Rotation effects
Buckwheat is a good green manure and offers growers an opportunity to clean up fall and spring annual weeds. The crop leaves little or no residues

Production costs and Marketing

Buckwheat has a low cost of production ($1 to $13/a) because of less weed and insect control costs. Currently buckwheat is grown under contract; McKay Seed Company at Moses Lake is currently the organization involved in growing and marketing of buckwheat as an identity preserved crop in the inland Northwest. There are two processing facilities available; one at Almira and one at Moses lake. There is a variable international market that requires larger kernels, higher test weight and a darker color. Seven to 10 days after dehulling grain, the seed oxidizes leaving a white kernel, which is then shipped whole.

Millet (*Panicum miliaceum* L.)

Description
Millet is one of the oldest cultivated grasses. Proso millet was introduced into the US. From Europe in the 18th century. Millet is a short season annual grass which is generally grown in semi-arid regions. It requires warm weather and has the lowest water requirements of any grain crop. However, it is not adapted to drought because of a shallow root system.

Uses. Millet is used for both human food and animal feed. Proso is similar to barely or oats in feeding value. Proso can also be cut for hay but Fowtail millet makes better hay.

Seeding date
Proso millet matures in 60 to 75 days and is generally grown as a late-season, summer catch crop. Millet establishes best when soil temperatures reach 65ºF. In evaluations we conducted at CBARC Pendleton and Moro, we seeded millet, together with other alternate crops at the end of April to mid May.

Seeding rate, depth and Row spacing
The seeding rate ranges from 10 to 25 seeds/ft^2. Seed millet to a depth of about 1 inch. In our evaluations, millet was seeded in 6-inch rows. Rows up to 8 inches have also been used.

Fertilizer rates
As in many grasses, nitrogen is usually the most limiting element. N rates should be based on soil test and yield goals. Rates ranging from 20 to 100 lbs N/acre are usually applied. Millets also require P and K. Apply P and K if test show <30 lbs P/acre.

Disease control
Proso millet is attacked by head smut (*Sphacelotheca destruens*) and kernel smut (*Ustilago crameri*). Treat seed for control. Crop rotations also help. Bacterial stripe (*Pseudomonas syringae*) also affects millet.

Weeds
Millet is a poor competitor with weeds and it is recommended to control weeds before seeding.

Insects
Grasshoppers and armyworms are major problem insects for most millets. However, these insects can easily be controlled by insecticides.

Flowering and Maturity
Millet is a short-season grass, which matures in about 60 to 75 days.

Harvesting
Millet can be harvested when seeds in the upper half of the panicle are mature. During this period, seeds in the lower half will be in the dough stage and leaves and stems will be green. Therefore, swath to allow drying of the straw before combining. Birds could be a problem during the ripening phases of the crop.

Yield potential
Grain yields of up to 2,800 lbs/acre have been obtained in Minnesota (Oelke et al., 1990). In our evaluation in 2002, grain yields ranged from 100 to 200 lbs/acre. The varieties used was not quite adapted to eastern Oregon conditions. Furthermore, the best management practices for millet in eastern Oregon have not yet been determined. More work should be done to improve millet yields in this region.

Rotation effects
Proso millet is a good rotational crop with most crops. Millet is seeded late as a summer catch crop. Millet does not utilize soil moisture deep in the soil profile because of shallow roots.

Production costs and Marketing
No pricing history exits for millet in the PNW. In general prices can range from $4/cwt to $15/cwt. About 450,000 acres of millet can be support by US markets. About 500,000 acres have been grown in the 1990’s in the US. There is some potential for export.

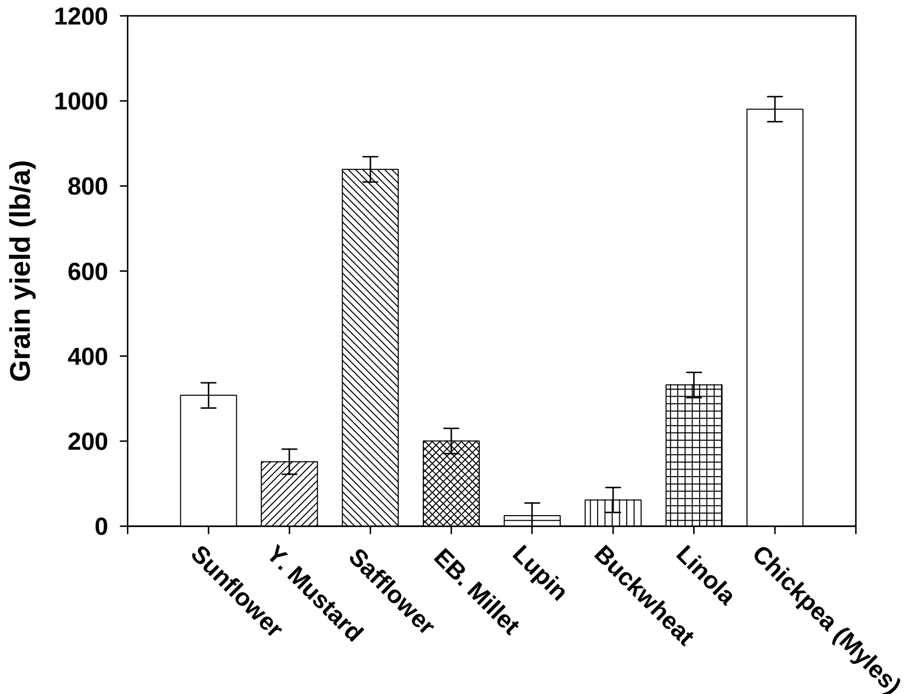

Fig. 1. Grain yield of alternative crops at CBARC, Pendleton in 2002.

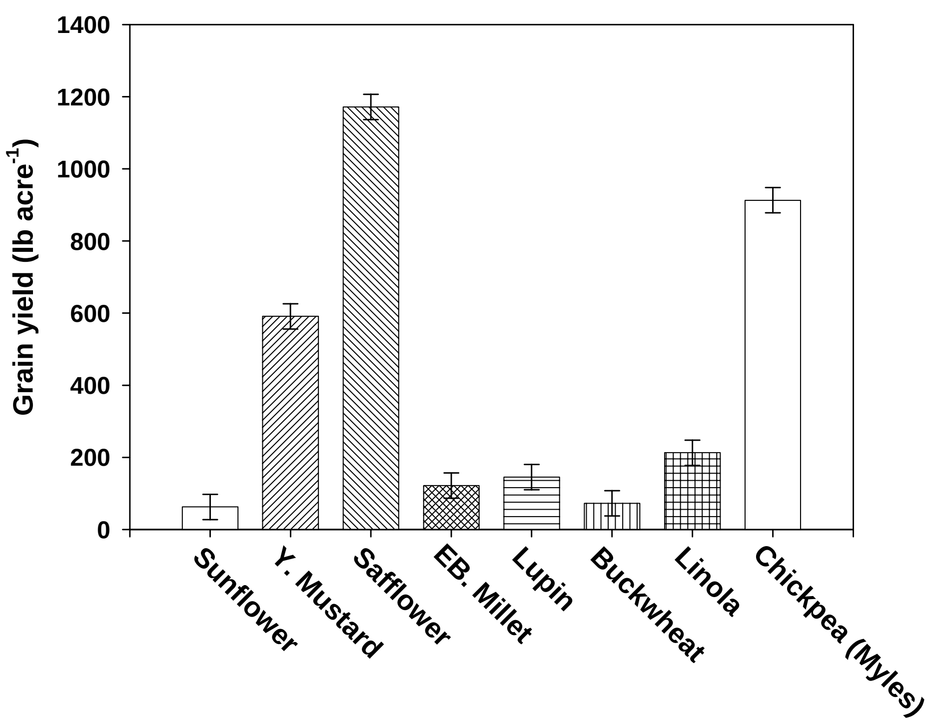

Fig.2. Grain yield of alternative crops at CBARC, Moro in 2002

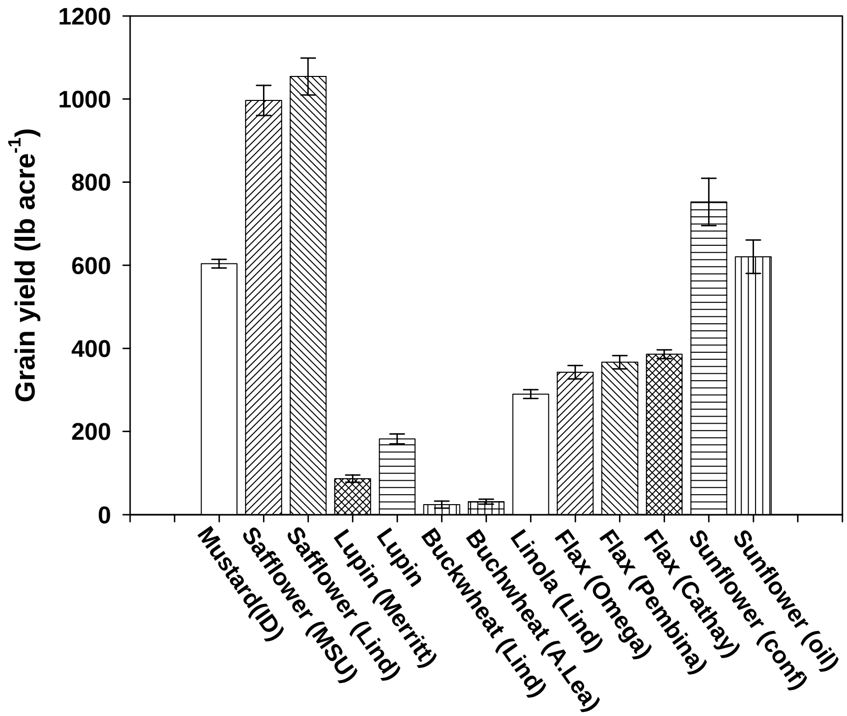

Fig. 3. Grain yield of alternative crops at CBARC, Pendleton, 2003

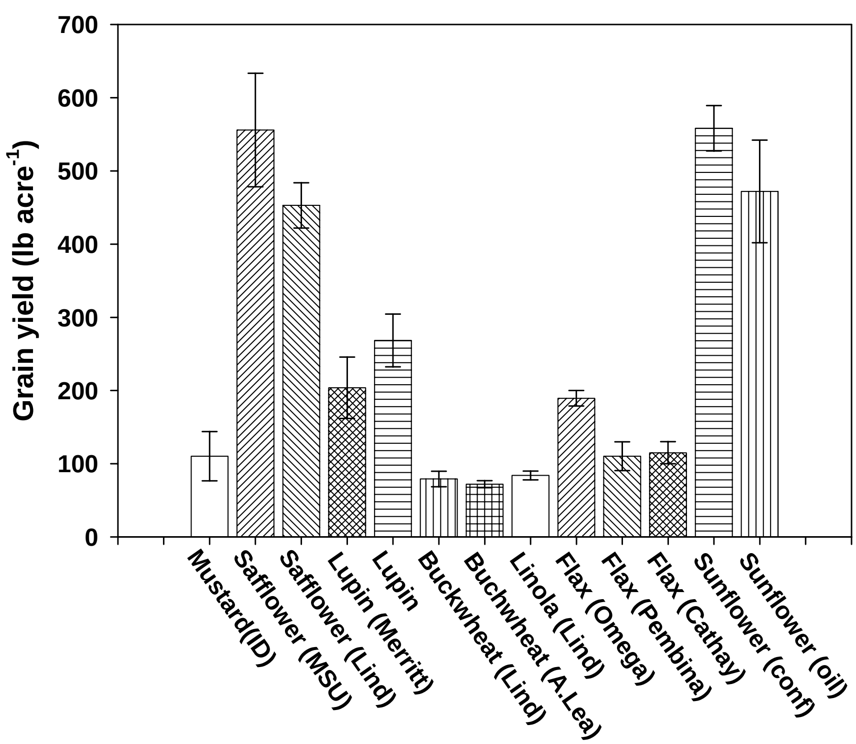

Fig. 4. Grain yield of alternative crops at CBARC, Moro, 2003

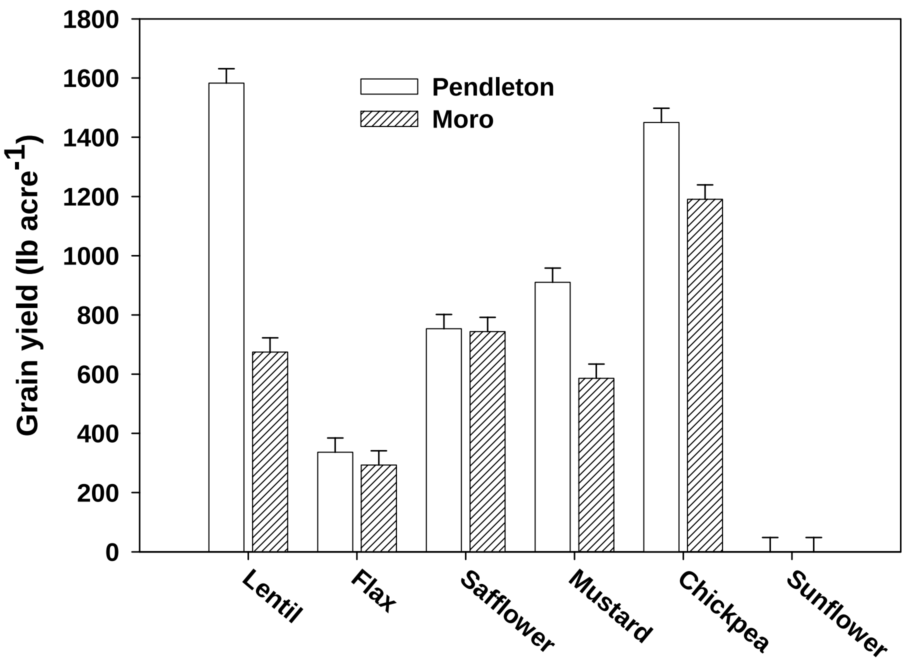

Fig. 5. Grain yield of alternative crops grown at Pendleton and Moro in 2004

Corn (*Zea mays* L.)

Description
Corn, also known as maize, is an annual subtropical cereal grass plant that originated in Mexico but it is now distributed all over the world and grows even in temperate climates where summers are reasonably warm. The plant is easily killed by frost. It is the world's fourth most important crop after wheat, rice, and potatoes.

Uses
Corn is used for human food (staple cereal in South America and Africa) and as animal feed as grain or fodder. Corn is eaten as a vegetable, as corn-on the-cob, fresh, canned or frozen. Corn is also used to make starch, syrup, oil, in the brewing of whiskey and other alcoholic drinks, and in the production of ethanol for energy needs.

Seeding date
Corn is planted after the last killing frost and when soil temperature reaches about 55ºF at a 2-inch depth. In our studies, we planted corn in May at both Pendleton and Moro.

Seeding rate, depth and Row spacing
Aim at obtaining 12,000 to 24,000 plants/acre in 30- to 40-inch rows. The desired population for dryland corn is 12,000 to 18,000 plants/acre. The seed should be placed in moist soil at about 1 to 2 inches depth.

Fertilizer rates
Nitrogen promotes rapid and vigorous growth and should be applied based on soil tests, soil organic matter, and expected yield. The NebGuide, a Nebraska Cooperative Extension Publication (G74-174-A) provides very detailed suggestions for fertilizing corn (Shapiro et al., 2003).

Disease control
Corn is attacked by a number of diseases. The most common disease of corn in the USA is corn smut. Corn is also attacked by rot diseases of roots, stalks, and ears.

Weeds
Corn is sensitive to weeds during the seedling stages. In dryland production, weeds compete for water with corn and will reduce corn yields substantially if not controlled. Summer annual broadleaf and grass weeds are most common.

Insects
Corn is attached by a number of insects; they include corn ear worm, European corn borer, grasshoppers, cutworms, rootworms, armyworms, sugarcane borer, grain weevils, aphids, white grabs, beetles, and bugs

Flowering and Maturity
Corn matures in about 90 to 130 days depending on variety.

Harvesting
Corn for fodder is harvested when grain is at about milk stage using a mower, sled or corn binder. At this stage corn can be used as silage or as dry forage. Corn for grain can be directly combine-harvested.

Yield potential
Average yields for silage corn is about 35,000 lbs/acre. Our results indicate that about 11,000 to 15,000 lbs/acre of fresh biomass that correspond to a dry weight of 4,000 to 6,000 lbs/acre can be produced under dryland conditions (Table 25). Grain weight ranged from 2,000 to 3,000 lbs/acre (Table 25). Grain yields of up to 18,000 lbs/acre have been produced. The average US. yields are about 5,000 lbs/acre. Plant population was rather high due to planter calibration problems. The high plant population probably decreased grain yield due competition for water and nutrients. The suggested plant population for dryland corn for grain is 12,000 to 18,000 plants/acre. The population can be increased if the corn is grown for silage.

Table 25. Biomass and grain yield of dryland corn, CBARC, Moro, 2004

Variety	Plant/acre	Biomass (lbs/acre)		Grain yield (lbs/acre)
		Fresh	Dry	
39F59	64,062	12,404	5,244	2,753
39T71	51,531	11,380	4,872	3,097
DKC26-75	44,823	12,520	5,228	2,036
DKC33-10	33,759	15,077	6,041	2,612
$LSD_{0.05}$	14,496	2,438	960	1,463

Rotation effects
Soybean, wheat, corn, and sorghum rotations are common in the Midwest. Rotations for dryland corn in the PNW have not yet been developed because it is a new crop. Under irrigation, however, corn is rotated with potatoes and wheat.

Production costs and Marketing

Expected returns above variable costs range from $30 to $80/acre under irrigation. Production costs and marketing for dryland corn have not yet been worked out for the PNW. Enterprise budgets are under construction.

Lupin *(L. albus L., L. augustifolius L., L. luteus L., L. mutabalis L., and L. cosentenii L.)*

Description

Lupin is a cool-season grain legume or forage crop. It is cultivated worldwide in climates ranging from northern Europe and the Caucaus Region, 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 Pacific Northwest at this time.

Lupin is one of the few grain legumes that compares to soybean in seed protein content (Hymowitz 1990). Lupin grain is high in protein and energy, low in fat and has a good fiber digestibility. The large seed and lack of anti-nutritional factors make lupin a potential crop for many animal feed formulations or for feeding as a whole grain as well as an excellent protein source for human consumption.

Current research, which has focused on spring narrow-leaf lupins varieties has demonstrated that lupin has the potential to be an important crop for this region. In recent experiments at Pendleton and Moro, varieties yielded more than 1,120 lbs/acres (Chen et al. 2001). Lupin yields in northern Idaho averaged less than 1000 lbs/acre. Although lupins possess an upright growth habit attractive for direct harvesting, their large seed size necessitates high seeding rates and good seed-bed conditions when planted with commercial small-grain drills. (Meuhlbauer 1993). The majority of the narrow-leaf lupin varieties tested to date have been shown to be poorly adapted to the low precipitation, short-season, dryland growing conditions in the Columbia Basin. USDA is currently exploring the development of narrow-leaf lupin varieties that would have better disease resistance and be more determinant in their growth habit.

Uses

Lupins are valued primarily for their high protein content and use as a high quality livestock feed. The major protein source of lupin seed is a group of globulins called conglutins. Conglutins make up approximately 85 percent of lupin's total protein and are similar in size and properties to the storage proteins of other legumes. The amino acid profile is good, with a high content of arginine, lucine, and phenylalanine. Lupin protein is deficient in the sulfur-containing amino acids lysine, methionine, and cysteine and must be supplemented for some animal feeds.

The oil content generally is higher than in other pulse crops and cereals but much lower than soybean and the oilseeds. Lupin protein and oil are more digestible than those of soybean, and lupins have low levels of the common antinutritional factors. Lupin seeds have little starch but are rich in dietary fiber, mainly in the cell wall material of the cotyledons. Lupin alkaloid levels vary, but are not a problem in narrow-leaf varieties. See Table 1 for protein, oil, and fiber comparisons between lupin species and soybean.

Table 26.—Composition of selected lupin species and soybean seeds (% of dry matter).

	Seed coat	Crude protein	Oil	Crude fiber
L. angustifolius	24	28–38	5–7	13–17
L. albus	18	34–45	9–15	3–10
L. luteus	24	36–48	4–7	15–18
Soybean	10	34	19	4

Adapted from: *Lupin Development Guide.*

Lupin flour is also used to produce an alternative flour source for people with gluten allergy. In France, lupin tofu and cheese products are produced using white lupin. It is thought that narrow-leaf lupin could be used for the same types of products. Research has shown that 10 percent lupin flour can be added to pastas and bread to make them more nutritious. The blend of cereal and legume helps to balance the amino acid profile and make a more complete food.

Adaptation

The ideal temperature for lupin growth is around 68 to 77°F during the day and 50 to 60°F at night. High temperatures (above 80°F) terminate branch development, shorten internode length, accelerate flowering and maturity, and increase flower abortion. Studies in Australia have shown that even 2 days of hot weather (80°F or greater) during bloom or when seed pods are filling can abort blossoms and reduce yields.

Low temperatures slow germination and emergence, increase susceptibility to brown leaf spot, delay flowering and maturity, increase flower abortion, and can cause frost damage to flowers.

Lupins are sensitive to soil pH, preferring acid to near-neutral conditions (pH of 4.5 to 7.5). They will tolerate slightly alkaline soils (to pH 8.0), providing the free lime or calcium content of the soil is low. They grow very well on sandy soils, deep sandy loams, and gravelly soils that allow for good taproot development. Good soil drainage is important for optimum growth.

Varieties
Due to Plant Breeder Rights (PBR) restrictions, only the public varieties Merrit and Gungurru are currently available for planting (Table 2). USDA is exploring the potential for developing narrow-leaf lupin varieties for Pacific Northwest.

Table 27.—Characteristics of two narrow-leaf lupin varieties.

					Tolerance			
Variety	Year of release	Flowering	Height	Early vigor	Brown leaf spot	CMV	Phomopsis	Drought
Merrit	1991	Early	Short	Med	MS	MS	R	MS
Gungurru	1988	Early	Short	Med	MS	MS	R	S

R = resistant; MS = moderately susceptible; S = susceptible

Adapted from *Producing Lupins in Western Australia.*

Seeding Date
By far the most important agronomic practice for getting good yield and height is early planting. Seed as early as temperatures allow and as soon as equipment can be used in the field. Narrow-leaf lupins can take some freezing temperatures and seem to have no problem with temperatures in the upper 20s Fahrenheit. However, although lupin needs to be sown early, sowing too early can result in poor stands due to disease pressure and nonuniform germination. Emergence usually takes 3-10 days depending on soil temperature.

Seeding Rate, Depth and, Inoculation
A seeding rate of 80 to 150 pounds per acre is recommended. In good environments, the lower density is adequate. Drought stress requires a higher density to maximize yield. Advantages of higher densities are better weed control, more uniform plant height and maturity, and increased ease of harvest. However, with higher densities, the cost of seed becomes a factor. Do not plant seed with a germination rate below 80 percent.

Seedbeds for lupin are similar to those required for small grains. The optimum seeding depth is 2 inches. In drier growing areas, the seed can be planted to moisture.

With lupin, there is no advantage to cultivation before planting. In fact, direct seeding can be advantageous. Because the cotyledons and growing point of lupin seedlings are above the soil, they are susceptible to sand blasting and insect damage. Residue from previous crops can protect the seedlings. Also, plowing buries weed seeds below the reach of preemergent soil herbicides and can bury *Pleiochaeta* disease spores to the root zone, where they will cause the most damage.

Lupins form a symbiosis with the root-nodule bacterium *Bradyrhizobium lupini*. Inoculation is recommended where lupins have not been grown before or if there has been an extended (4- to 5-year) gap between lupin crops. Use a group G inoculum.

Commercial peat inoculant has traditionally been used with lupins. Research in Canada has shown significant benefits of granular inoculants as compared to peat types. Research at the Columbia Basin Agriculture Research Center, Moro is currently evaluating the use of granular inoculants with legumes in this region. Make sure any fungicides and insecticides are compatible with inoculants. Sow seed as soon as possible after treatment. Sowing with high rates of superphosphate or with superphosphate containing trace amounts of copper sulfate may lead to nodulation failure.

Fertilizer Rates

A well-nodulated lupin crop does not need nitrogen fertilizer. In most cases, lupin is used as a source of nitrogen in the farming system, and nitrogen fertilizer application to the crop is rare.

Excess applied nitrogen may promote vigorous early growth, but it can inhibit or delay nodulation and nitrogen fixation even when nodules form. Nitrogen application rarely increases yield, but often stimulates weed growth.

Based on studies conducted at the Columbia Basin Agricultural Research Center (Pendleton) and the Sherman Experiment Station (Moro), the application of N-containing starter fertilizer at planting greatly suppressed lupin seedling emergence, thereby affecting seed yield. Starter fertilizer without N did not affect seedling emergence and yield.

Good levels of soil phosphate are needed for maximum vegetative growth and yield. Lupins will respond to high rates of superphosphate on phosphorus-deficient soils. However, rates above 180 pounds per acre produce toxicity and reduce seedling emergence when drilled with the seed. If more than 180 pounds per acre of superphosphate are needed, apply it in a deep band before sowing. High rates of superphosphate also tend to make potassium and manganese uptake more difficult for the lupin plant.

Manganese (Mn) deficiency manifests itself as a split seed disorder. Split seed can occur after a short dry spell or during pod filling after prolonged dry conditions. Manganese uptake is poor in dry topsoil, and Mn is relatively immobile in the plant so it does not move into areas of new growth. Early sowing and higher seeding rates reduce the risk of split seed, as the seed will fill and mature before soil moisture is exhausted.

Disease Control
Lupin diseases fall into four main categories: root, leaf, stem, and virus. In Australia, the most important are fungal diseases caused by *Pleiochaeta, Rhizoctonia*, and *Anthracnose*.

In the Columbia Basin lupin research trials, late-planted fields showed signs of disease pressure. Powdery Mildew, bacterial pod blight and leaf spot have been observed in research plots. The limited data from these trials suggest that early planting and insect control can help reduce disease problems. However, as lupin acreages increase, so will the potential for disease problems.

Insects
Narrow-leaf lupin has not been grown long enough in the Columbia Basin to get a true picture of which insects will affect the crop. In OSU lupin trials, army cutworm, false wireworm, true wireworms and aphids have been found. Seed treatments and foliar insecticide treatments can be used for control of these pests.

Weeds
Weed competition is one of the biggest constraints to producing lupins. The lupin canopy develops slowly, allowing weeds to germinate and grow over a long period of time. Late-germinating broadleaf weeds are especially problematic. For this reason, weed control is essential for success with lupin. Avoid fields with heavy weed populations, especially perennial weeds. Rotate crops to avoid weed buildup.

Weeds of particular importance in Pacific Northwest (PNW) lupin production include kochia, Russian thistle, prostrate knotweed, and winter annual grasses, including volunteer cereals.

Weed control is accomplished through the use of mechanical control and herbicides. Herbicides that are currently registered for use with lupin include pendimethalin, metolachlor, sethoxydim, and paraquat, but the spectrum of weeds controlled by these compounds does not fit well with existing weed control needs in the PNW. Additional herbicide screening will need to be done if large-scale commercial production of lupin is to be successful in the region.

Growth Habit, Flowering and Maturity
The life cycle of lupins can be divided into three stages: vegetative phase, floral phase, and pod and seed growth phase. The rate at which the plant progresses through each phase depends on temperature and day length.

Growth stages are referred to in terms of leaf number (for example, four-leaf stage). The internode length and plant height at the start of flowering are affected by temperature and light. Given optimum temperatures, both leaf area and dry matter increase more slowly in lupins than in cereals. Slow early growth can affect the crop's ability to compete with weeds and can increase disease and insect damage.

Branches develop in the leaf axils below the main stem inflorescence and are referred to as orders. Most well-grown lupin crops have multiple orders (branches). In dry seasons, only a few first-order branches may develop. The vigor and extent of lupin branching varies both within and between lupin species.

Lupin develops a single main taproot with lateral branches. In sandy soils, roots can reach 1 meter in depth within 6 weeks of sowing even when the shoot is still small. This rapid root growth allows lupin to use nutrients that are unavailable to wheat's shallow, fibrous root system. As the taproot grows, it develops nitrogen-fixing nodules and lateral roots.

Lupin can produce as many as 70 flowers on the main stem. The flowers open in ascending order, usually one or two per day. Lupins are strongly self-pollinating, so almost all flowers are fertilized and capable of forming pods.

After fertilization, the flower ovary develops into a pod, or the flower dies and drops off. Flower abortion on the main stem is dramatic; 80 to 90 percent of all flowers are aborted. This abortion is normal in legumes. However, due to the compensatory ability of different branch orders, good yields are possible even with poor pod set on the main stem. Even with 70 percent flower abortion on a plant as a whole, lupin is capable of very high yields.

Floral abortion is intensified by moisture stress, low temperatures (below 50°F), and high temperatures (above 80°F) at flowering. Pod set is decreased under very favorable growing conditions, as ample soil moisture and cool, cloudy weather promote vegetative rather than reproductive growth.

Most lupin pods are capable of producing four to five seeds. Generally, larger seeds are produced on the main stem and under cool ripening conditions.

In 14 to 20 weeks, flowering ceases, and maximum dry matter is reached. All of the plant's nutrients are redirected from growth to seed filling. The crop is physiologically mature when the moisture content of the seeds falls to about 40 percent. At this stage, stems and leaves are light green to yellow, leaf drop starts, and the cotyledons of the seeds are green. The rest of the crop season is primarily a drying process.

Harvesting

Lupins are harvested when grain moisture is 12-15%. In some seasons, stems are still pale green at this time. Delays can result in significant yield losses due to lodging, pod shattering, and pod drop. Lupins must be harvested within 3 weeks of maturity.

A major consideration of lupin production is harvest loss and can range from 5-40%. Mechanical harvest of lupin is more difficult than harvest of small grains. Inadequate crop height and loss from the front of the combine header are problems currently encountered in grower drill strip tests. Various harvest techniques and combine modifications can be used, including stripper header harvest, use of combine air reels, and sickle bar modifications. Field losses due to shattering can also be avoided or reduced by harvesting in the early morning or late evening, when moisture is more likely to be present on the pods. Avoid combining in extreme heat

Yield Potential

Yield potential in lupins is determined by the production of successive orders of inflorescences produced on ancillary branches. Lupin yields decline more rapidly than cereals as the sowing date is delayed and the effective growing season shortened. The sensitivity of narrow-leaf lupin to high temperature in spring is an additional reason for early sowing. Examples of yields are found in table 28.

Table 28.—Yield of lupin at Pendleton and Moro, Oregon, sites in 1998 and 1999.

	Moro*		Pendleton*†	
	1998 Yield (lb/a)†	1999 Yield (lb/a)†	1998 Yield (lb/a)†	1999 Yield (lb/a)†
Merrit	1,237a	1,162a	779a	1,220b
Yorrel**	702b	1,132a	488b	1,581a
Chittick**	32c	1,313a	1d	1,613a
Danja**	569b	1,250a	303c	1,381a,b

*Moro rainfall was 12.22 and 8.35 inches for the cropping season (September–August) in 1997–1998 and 1998–1999, respectively (91-year average = 11.46). Pendleton rainfall was 15.57 and 18.35 inches for the cropping season (September–August) in 1997–1998 and 1998–1999, respectively (71-year average = 16.54).

†Means in the same column followed by the same letter are not significantly different according to the LSD (P= 0.05).

**Varieties not commercially available in the United States.

Rotational Effects

Lupin as a legume would be an excellent rotational crop with small grains. Benefits include fixing nitrogen (20-40lbs/a/yr) as well as serving as breakcrop to reduce small grains diseases, weeds and insect pests.

Production and Marketing
The value of Lupin value is based upon the prices of other protein sources particularly soybeans. Using the rule-of-thumb that lupin has a value of 75% of the value of soybean meal, this would equal $135/ton for lupin. A lupin yield of 1200lb/a/yield would have a gross value of $81/acre.

There are several markets available for lupins. The seed can be fed directly to poultry and livestock, either whole, cracked, or ground. Lupin can replace soymeal in livestock rations. Lupin flour can be incorporated into food products for human consumption. In the short term, lupin markets will need to be local to reduce transportation costs and increase the profit margin. In the future, Oregon growers could compete with Australia in international markets.

Indian Ricegrass (*Achnatherum hymenoides*, *Oryzopsis hymenoides*)

Description

Indian Rice Grass is a cool-season, long-lived perennial bunchgrass that grows up to 2 ft tall. It is native to the arid and semiarid regions of the western United States, and is considered valuable as winter forage, and is one of the most drought tolerant native rangeland grasses (Jensen et al., 2001). The seeds of Indian ricegrass, were also formerly used by Indians for grinding into meal and making bread and currently are being used as a grain substitute for those who are gluten-intolerant.

Adaptation

Indian ricegrass's area of adaptation extends from the Dakotas south to Texas and west to the Pacific Ocean to Canada at elevations up to 8,000 ft. It is well adapted to dry sandy soils that have up to 75% sand and receive at least 7 in of average annual precipitation. Indian ricegrass will tolerate moderately alkaline soils (Jensen et al., 2001). In the Columbia Basin, it has been shown to be adapted to the silt loams soils, but has done very poorly in the heavier clay loams.

Uses

Indian ricegrass is valued as a high quality winter and early spring forage by all classes of livestock and wildlife. The seeds are relished by both livestock and wildlife because of the high protein and fat content (Hafenricher et al., 1968). When cut for hay, the forage cures well and is frequently stock piled for winter feed. When grown for seed, crop aftermath is has been shown to be a valuable source of feed.

Indian ricegrass is an important species for conservation reserve programs and reclamation projects particularly on those sites with very sandy soils particularly in rangeland and forest environments. As a native plant, it is well adapted for use in landscaping and xerscaping around homes.

Indian ricegrass recently has been identified for use as a grain substitute for those who are gluten intolerant. People who suffer from gluten intolerance (Celiac disease) have a genetic autoimmune disorder that reacts to the gluten/gladden proteins in wheat, barley, rye and other small grains. It is estimated that 1 in 150 people have some degree of gluten intolerance with over 1.5 million people in the US alone. Current markets for gluten-free products such as breads, cookies, cereals etc. is over $400 million per year (Johnson).

Seeding Date

Indian ricegrass can be successfully planted in early fall with irrigation (Sexton 2000) under dryland conditions in late fall when soil temperatures are below 47 F and in early spring seedings (Johnson 2002). Indian ricegrass seed has high seed dormancy, which results in poor first year germination. Seed dormancy can be reduced by sulfuric acid, mechanical scarification, using older lots of seed, seeding depth or through pre-chilling (Jensen et al., 2001). It has been demonstrated that pre-chilling one-year-old seed for four weeks increased germination by up to 35% (Ball 2002). It needs to be stressed that it can take up to two years to fully establish a stand particularly if the seed is not pre-treated. Even with pre-treatments there will still be plants that will not emerge until the second year.

Seeding Rate and Depth

In Montana, suggested seeding rates range from 4 lbs for fall seedings to 6-8 lbs for spring seedings (Johnson 2002). Experience in the Columbia Basin suggests seeding rates of at least 8 lbs (25 seeds per ft2) using narrow row spacing to promote more uniform stands and better competition with weeds. Higher seeding rates insure better initial stands and increased competition with weeds. This is particularly important for late fall seedings. Late fall seedings, which germinate in the spring can experience severe crusting problems particularly with soils low in organic matter. The thick crust greatly reduces seedling emergence. Because of the crusting problem, in limited trials in the Columbia Basin, spring seedings have been shown to have better emergence.

As noted high seed dormancy is an issue with Indian ricegrass. Planting depth can be up to 3 inches on sandy soils depending on pre-treatments and soil types. Planting untreated seeds deeper into soil moisture will enhance the breakdown of the hard seed coat and promote germination (Jensen et al., 2001). In silt loam soils, planting depth needs to be in the range of 3/8 to 3/4 inch.

Seedbed condition and preparation is critical to obtaining a successful stand. A firm seed bed and good seed soil contact is critical. Use of no-till drills works well with Indian ricegrass as long as the seed is adequately covered and soil firmed around the seed. Where tillage is used, the seed bed should be firm and if needed, rolling prior to seeding will significantly enhance emergence particularly for spring seedings.

Varieties

Traditional, adapted varieties include Nezpar, which is adapted to northern areas and Paloma, which is better adapted to southern areas. The most recent variety of Indian ricegrass and the one that was used in the Columbia Basin trials is Rimrock. Rimrock has similar growth habit and forage quality to the other varieties is less susceptible to seed shattering. (Jensen et al., 2001).

Fertilizer Rates
Fertilization rates should be based upon soil sampling. Suggested amounts of nitrogen range from 30-50 lbs per acre for dryland and 50-80 lbs for irrigated. Apply phosphorus, potassium and sulfur at forage production rates.

Disease and Insect Control
No disease or insect pest problems have been observed to date.

Weeds
Weed control in Indian ricegrass stands is very important for two reasons. The first and most obvious is to reduce competition. Indian rice grass is not a strong competitor, so good weed control is critical to provide optimum production. A second very critical reason is contamination with grassy weeds that might contain gluten particularly volunteer small grains. To sell Indian ricegrass grain for human consumption there cannot be ANY contamination. So, good weed control and management that will reduce the likelihood that a seed lot will be rejected is a must.

To obtain a successful stand, it is critical to start out with a very clean weed free field. Fallowing the field at least one year prior to seeding and use of spring seedings will greatly reduce weed control problems. Grassy weeds are a particularly difficult problem as controls will kill Indian ricegrass seedlings. Broadleaf weed control is easier, but lower labeled rates are used on Indian ricegrass seedlings until they become established. As previously noted, it can it can take two years to establish a stand, so use of herbicides has to be carefully considered as many will kill Indian ricegrass seedlings.

Indian ricegrass grows much slower than a number of grassy and broadleaf weed problems. Tools including clipping and use of weed wipers to kill weeds as they over top the Indian ricegrass seedlings can be effective. Again, having a very clean field prior to planting is one of the best weed control options with Indian ricegrass.

Irrigation
In limited Columbia Basin trials, it has been shown that 2-4 inches of additional irrigation can significantly increase yield particularly in drought years. Studies in Montana have shown at least a doubling of yields with irrigation as compared to dryland (Johnson 2002). One issue that became apparent in the Columbia Basin trials was with overhead sprinkler use during grain maturity, which resulted in reduced yields. Irrigation needs to be turned off prior to flowering and avoided during seed ripening to prevent severe losses. Irrigation should be turned back on after harvest to promote fall growth (Smith).

Additional irrigation has also shown to be beneficial in establishing the crop in drought years. Observations in the Columbia Basin have shown that Indian ricegrass plants, which are slow growing in the early stages, typically have shallow root systems the first two years of growth. Drought early in the spring can reduce plant vigor and root establishment. Providing some additional water can greatly reduce the effects of drought and improve crop establishment. For information concerning crop water use and evaportranspiration in the Columbia Basin, please see Oregon Crop Water Use and Irrigation Requirements, OSU EM 8530.

Maturity

Indian ricegrass typically begins to mature in mid to late June. It has an indeterminate maturation, producing seed over a prolonged period (Johnson 2002). Seeds are black in color when mature.

Harvest

During the first year of growth, under average conditions Indian ricegrass will produce a small crop which can be harvested. The second and third years will see significant increases in production. Average stands, if properly managed, will last over 10 years. Note plants during the first and second years have shallow root systems, so care needs to be exercised in harvesting to avoid pulling up plants. Following harvest, the straw is often baled for livestock feed.

Harvest at the hard dough stage to when the first seed shatters (Johnson 2002). The best average harvest will be obtained after the first seed drop. Seed will appear on the glumes as a small, fuzzy gray/white mass. After swathing, Indian ricegrass should be allowed to field cure until stems are easily broken and seed can be threshed by hand from the panicle (Johnson 2002).

Combine setup suggestions: ground speeds should be kept to approximately 1.5-2 mph; cylinders opened to 3/8" to 1/8"; low air flow; 800-1100 rpm cylinder speeds, and operate combine at full capacity. Avoid overloading sieves and cylinders (Johnson 2002). Store harvested grain at 12% moisture. Note seed will need to be taken to a cleaning facility for debearding and final cleaning. Most field run seed will be at least 50% or more dockage.

When harvesting grain for human consumption, harvest equipment (combine, trucks, augers etc) must be in totally clean of contamination from small grains and weed seeds and dust that have gluten to avoid cross contamination

In years with late spring rains or where irrigation is used, a second lighter crop can be expected approximately a month later based upon trials in the Columbia Basin.

Yields

The following grain yields were obtained in 2003; the second year for the fall seeded crop and one year for the spring seeded crop (Table 29, 30). Under dryland conditions, grain yields were significantly higher at Pendleton than at Moro. Irrigation significantly increased grain yield of the Indian Rice grass. Grain yields were low compared to potential yields. One of the contributing factors for low yields was due the learning curve with this crop with respect to optimal production and harvesting. Much of the seed had shattered and blown away due to the wind by the time it was harvested. We also used small plots, which made harvesting difficult. All these factors led to very high CV%. To remedy the situation, we plan to seed the grasses in very large plots to evaluate the true potential of the grasses in eastern Oregon.

Table 29. Grain yields of Indian Rice Grass at CBARC, Pendleton, 2003.

			Indian Ricegras
Planting date	Grass Type	Seeding Rate (seeds/ft)	Grain yield (Lbs/a)
Nov 7, 2001	Indian Rice Grass	25	133.5
		50	113.6
		75	53.1
	mean		**64.1**
Mar 28, 2002	Indian Rice Grass	25	178.6
		50	28.5
		75	89.6
	mean		**98.9**
$LSD_{0.05}$	-	-	99.8

CV%=98.5

Table 30. Grain yields of Indian Rice Grass at CBARC, Moro, 2002.

			Grain Yield (Lbs/a)	
Planting date	Grass Type	Seeding Rate (seeds/ft)	Dryland	Irrigated
Nov 7, 2001	Indian Rice Grass	25	25.6	94.8
		50	29.8	32.0
		75	22.7	283.6
	mean		**26.0**	**136.8**
Mar 28, 2002	Indian Rice Grass	25	29.1	464.5
		50	70.4	526.6
		75	60.2	213.5
	mean		**53.2**	**401.5**
$LSD_{0.05}$	-	-	39.7	402.3

CV%=166

In addition to the aforementioned yields, in 2004, we hand harvested the Moro crop, taking sub-samples from the various plots. Sampling was done at the more optimal time of harvest, which is at first seed drop. Average yields were 752 lbs per acre for irrigated and 931 lbs per acre for dryland. The reason for the lower yields with the irrigated plots was due to shatter losses from overhead sprinklers and late spring rains, which negated the benefits of irrigation. It was also noted that the grain was slightly (1-2 weeks) later in maturity with the irrigated as compared to the dryland plots. This was noted due to the approximately 20% loss of grain at time of harvest due to shatter. Hand harvested yields in 2004 are felt to be a better reflection true yields due to more optimal harvest date and expected handling losses than those of the earlier 2002 and 2003 yields.

Rotation Effects

Indian ricegrass will provide some very important benefits as a rotation crop. In sampling CRP fields in the Columbia Basin, it has been demonstrated that there have been increases in organic matter by over 1%, after 10 years of growth. With the long-term nature of Indian ricegrass production, it is anticipated that the production of Indian ricegrass could provide real benefits through increased soil quality, organic matter, water holding capacity and fertility and reduced pest problems.

Production Costs and Marketing

Expected returns could be as high as $300 to over $1,000 per acre per year depending on end-use. Specific production and marketing costs for Indian ricegrass have not yet been worked out for the PNW. Enterprise budgets are under development.

Green Needlegrass (Stipa viridula)

Description

Green needlegrass is a cool-season perennial bunchgrass that grows up to 4 ft tall (Stechman 1986). It is a native to the semi-arid intermountain west and as a secondary constituent of the native prairie of the northern Great Plains (Hughes 51). It is very winter hardy, moderately tolerant to flooding and has a low tolerance to shade. Many of the needlegrasses occur as important components within natural plant communities from grasslands to open timber They are important forage and cover species in many areas for both livestock and wildlife. Of the needlegrasses, only green needlegrass, which is used on reclamation projects, has been successfully commercialized for seed production (Jensen et al., 2001). It is also gluten-free and is being considered for use as a grain substitute for those who are gluten-intolerant.

Adaptation

Green needlegrass is adapted to a wide range of soils, but prefers light (sandy), medium (loamy) and heavy (clay) textured soils on sites receiving 10-26 inches of annual precipitation (Smoliak et al.). The plant prefers acidic, neutral and can moderately tolerate basic (alkaline) soils. Green needlegrass has a deep up to 10' fibrous root system. It often occupies the plains and foothills at fairly low elevations and is common on mountain meadows and open hillsides up to 9,000 ft in Wyoming and Montana. At the southern limit of its range, green needlegrass occupies dry, open parts and canyons within the ponderosa pine belt (Jensen et al. 2001).

Uses

Many of the needlegrasses are important forage species and provide good spring, summer and fall grazing, but will decrease under grazing (Smoliak et al). Deferring spring grazing will benefit the grass. It retains nutritive value even when dry and somewhat tough. Following seed maturity, needlegrasses regenerate readily (Stechman 1986). The presence of long awns (3/4 to 1 1/4 in) on green needle grass, cause it to be avoided by livestock and wildlife at maturity (Jensen et al., 2001).

Green needlegrass is an important species for conservation reserve programs and reclamation projects particularly on those sites that are droughty and have heavy soils particularly in rangeland and forest environments (Jensen et al., 2001). As a native plant, it is well adapted for use in landscaping and xerscaping around homes.

Green needlegrass recently has been identified for use as a grain substitute for those who are gluten intolerant. People who suffer from gluten intolerance (Celiac disease) have a genetic autoimmune disorder that reacts to the gluten/gladden proteins in wheat, barley, rye and other small grains. It is estimated that 1 in 150 people have some degree of gluten intolerance with over 1.5 million people in the US alone. Current markets for gluten-free products such as breads, cookies, cereals etc. is over $400 million per year (Johnson 2002).

Seeding Date

Green needlegrass can be successfully planted in early fall with irrigation (Sexton 2000) and in late fall when soil temperatures are low and in early spring seedings under dryland conditions. Green needlegrass seed has high seed dormancy, which results in poor first-year germination. Seed dormancy can be reduced by wet pre-chilling in moist sand, acid or mechanical scarification or using older seed lots (Jensen et al., 2001; Ball 2002). One-year-old seed has a germination of 26%, which increases to year 7, and then decreases to 0% at year 21. It needs to be stressed, that it can take at least two years to fully establish a stand, particularly if the seed is not pre-treated. It should also be noted from experience in the Columbia Basin, green needlegrass does well in filling in the spaces between rows following the second year of production.

Seeding Rate and Depth

Experience in the Columbia Basin suggests seeding rates of at least 6 lbs (25 seeds per ft2) and preferably 12 lbs (50 seeds per ft2) using narrow row spacing to promote more uniform stands and better competition with weeds. Higher seeding rates insure better initial stands and increased competition with weeds. This is particularly important for late fall and early spring seedings. Late fall seedings, which germinate in the spring can experience severe crusting problems, which greatly reduces emergence. This seems to be more of a problem in soils with low organic matter. Because of the crusting problem, spring seedings have been shown to have better emergence in the Columbia Basin. This is contrary to most research, where fall seedings increase time of seed to soil contract, which helps to breakdown dormancy.

Planting depth should be in the range of 1/4 to 1/2 inch depending on pre-treatments and soil types (Jensen et al., 2001).

Seedbed condition and preparation is critical to obtaining a successful stand. A firm seedbed and good seed soil contact is critical. Use of no-till drills works well with green needlegrass as long as the seed is adequately covered and soil firmed around the seed. Where tillage is used, the seedbed should be firm and if needed, rolling prior to seeding will significantly enhance germination particularly for spring seedings.

Varieties
Two varieties of green needlegrass are commercially available. Green stipagrass, which is noted for its increased forage and seed yield, seedling growth and regrowth characters when compared to common green needlegrass, and the variety Lodorm, selected for its low seed dormancy (Jensen et al., 2001).

Fertilizer Rates
Fertilization rates should be based upon soil sampling. Suggested amounts of nitrogen range from 30-50 lbs per acre for dryland and 50-80 lbs for irrigated. Apply phosphorus, potassium and sulfur at forage production rates.

Disease and Insect Control
No disease or insect pest problems have been observed to date.

Weeds
Weed control in green needlegrass stands is very important for two reasons. The first and most obvious is to reduce competition. Green needlegrass is a good competitor when properly managed. Good weed control is critical to provide optimum production. A second very critical reason is contamination with grassy weeds that might contain gluten, particularly volunteer small grains. To sell green needlegrass grain for human consumption, there cannot be ANY contamination. So, good weed control and management that will reduce the likelihood that a seed lot will be rejected is a must.

To obtain a successful stand, it is critical to start out with a very clean weed free field. Fallowing the field at least one year and using spring crops prior to seeding green needlegrass will greatly reduce weed control problems. Grassy weeds are a particularly difficult problem as chemical controls will kill green needlegrass seedlings. Broadleaf weed control is easier, but lower labeled rates are used on green needlegrass seedlings until they become established to reduce injury. As previously noted, it can it can take two years to establish a stand, so use of herbicides has to be carefully considered as many will kill green needlegrass seedlings.

Green needlegrass grows slower than a number of grassy and broadleaf weed problems. Tools including clipping and use of weed wipers to kill weeds as they over top the green needlegrass seedlings can be effective. Again, having a very clean field prior to planting is one of the best weed control options with green needlegrass

Irrigation
In limited Columbia Basin trials, it has been shown that 2-4 inches of additional irrigation can significantly increase yield particularly in drought years. One issue that became apparent in the Columbia Basin trials was with overhead sprinkler use during grain maturity, which resulted in reduced yields. Irrigation needs to be

turned off prior to flowering, and avoided during seed ripening to prevent severe losses. Irrigation should be turned back on after harvest to promote fall growth (Smith).

Additional irrigation has also shown to be beneficial in establishing the crop in drought years. Observations in the Columbia Basin have shown that green needlegrass plants, which are slow growing in the early stages and typically have shallow root systems. Drought early in the spring can reduce plant vigor and root establishment. Providing some additional water can greatly reduce the effects of drought and improve crop establishment. For information concerning crop water use and evaportranspiration in the Columbia Basin, please see Oregon Crop Water Use and Irrigation Requirements, OSU EM 8530.

Maturity
Green needlegrass typically begins to flower in early June with mature grain by mid to late June. Heads mature from the top down over a period of several weeks. Seeds are brown in color when mature.

Harvest
During the first year of growth, under average conditions green needlegrass will produce a small crop, which can be harvested. The second and third years will see significant increases in production. Average stands, if properly managed, will last over 10 years. Note plants during the first and second years have shallow root systems, so care needs to be exercised in harvesting to avoid pulling up plants. Following harvest, the straw can be baled for livestock feed.

As noted harvest occurs over several weeks with heads maturing from the top down over a period of 4-6 weeks. Begin harvest when mature seed easily strips off the head. Harvesting is accomplished by using a seed stripper, which removes the seed without damaging the plant. Several passes will need to be made over 4-6 weeks as the grain matures to obtain maximum yield. There are several companies that make seed strippers, which can be used on ATVs for small acreages to tractor size models for larger fields. Most field run seed will have over 50% dockage.

When harvesting for grain for human consumption, harvest equipment (combine, trucks, augers etc) must be totally clean of contamination from small grains and weed seeds and dust that have gluten to avoid cross contamination

Yields
The following grain yields were obtained in 2003; the second year for the fall seeded crop and one year for the spring seeded crop (Table 31, 32). Under dryland conditions, grain yields were significantly higher at Pendleton than at Moro. Irrigation significantly increased grain yield of the green needlegrass. Grain yields were low compared to potential yields. One of the contributing factors for low yields was due the learning curve with this crop with respect to optimal

production and harvesting. Much of the seed had shattered and blown away due to the wind by the time it was harvested. We also used small plots, which made harvesting difficult. All these factors led to very high CV%. To remedy the situation, we plan to seed the grasses in very large plots to evaluate the true potential of the grasses in eastern Oregon.

Table 31. Grain yields of Green Needlegrass at CBARC, Pendleton, 2003.

Planting date	Grass Type	Seeding Rate (seeds/ft)	Grain yield (Lbs/a)
Nov 7, 2001	Green needlegrass	25	106.3
		50	84.5
		75	65.0
	mean		**85.3**
Mar 28, 2002	Green needlegrass	25	66.9
		50	72.7
		75	95.4
	mean		**78.3**
$LSD_{0.05}$	-	-	99.1

CV%=98.5

Table 32. Grain yields of Green Needle Grass at CBARC, Moro, 2002.

			Grain yield (Lbs/a)	
Planting date	Grass Type	Seeding Rate (seeds/ft)	Dryland	Irrigated
Nov 7, 2001	Green Needlegrass	25	6.7	59.9
		50	22.1	78.1
		75	16.3	60.1
	mean		**15.0**	**66.0**
Mar 28, 2002	Green Needlegrass	25	37.8	67.5
		50	20.2	52.5
		75	31.2	37.1
	mean		**29.7**	**52.4**
$LSD_{0.05}$	-	-	15.1	329.6

CV%=166

In addition to the aforementioned yields, in 2004, we hand harvested the Moro crop, taking sub-samples from the various plots. Sampling was done at the more optimal time of harvest, which was when the top 1/3 of the heads were mature. Harvest was at 7-10 day intervals over 4 weeks for dryland and 6 weeks for irrigated plots. Irrigated plots tended to have a longer harvest due to additional head production off the main stems. Hand harvested yields in 2004 were felt to be a better reflection of expected yields due to more realistic harvest and handling losses and multiple passes over the field as the grain matured. In crop years 2002 and 2003 fields were harvested only once using a small grains combine.

Average yields in 2004 for the dryland plots were 493 lbs/acre with a range of 312 to 749 lbs/acre. Irrigated plots had an average yield of 507 lbs/acre with a range of 312 to 704 lbs/acre. It is felt, the reason irrigated yields were not significantly higher than the dryland yields was due to shatter losses from overhead irrigation during grain maturity and significant late spring rains in early June. This negated much of the benefit of any additional irrigation. Typical yields for seed production in Montana averaged 100 lbs/acre for dryland and 250 lbs/acre for irrigated production (Smoliak et al).

In 2004, plant heights were also measured at harvest. Dryland plants were on the average 4' tall, and heads averaged 7-8" in length. Irrigated plants were on the average 4.5' tall, and heads averaged 8-9" in length.

Rotation Effects

Green needlegrass will provide some very important benefits as a rotation crop. In sampling CRP fields in the Columbia Basin, it has been demonstrated that there have been increases in organic matter by over 1%, after 10 years of growth. With the long-term nature of green needlegrass production, it is anticipated that the production of green needlegrass could provide real benefits through increased soil quality, organic matter, water holding capacity and fertility and reduced pest problems.

Production Costs and Marketing

Expected returns could range from $300 to over $1,000 per acre per year depending on end-use. Specific production and marketing costs for green needlegrass have not yet been worked out for the PNW. Enterprise budgets are under development.

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