Adaptation and Yield of Spring and Fall Sown Safflower in Northeastern Oregon

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Abstract

Safflower, a drought tolerant oilseed crop, may be adapted to eastern Oregon dryland cropping conditions. Safflower seeds can be sold for bird feed and the oil can be used for cooking and as a biodiesel feedstock. In our preliminary evaluations at Moro and Pendleton, spring safflower grain yields ranged from 400 to 1400 lbs/acre. Spring safflower was more productive than other possible alternative crops such as buckwheat, lupins, and linola. Recently, winter hardy facultative safflower lines have been developed that permit the seed to be sown in the fall or in the spring. Yield of fall sown safflower was as high as 1,900 lbs/acre. Fall seeding resulted in earlier flowering and maturity and increased yield compared to spring seeding.

Key Words: Alternate crops, fall safflower, spring safflower

Introduction

Safflower is an annual domesticated broadleaf thistle with a strong central branch stem, a number of branches and a large tap root system that may penetrate to a depth of 10 ft under optimum conditions. It is an oilseed crop that is well adapted to the low summer rainfall cereal grain production areas of the western Great Plains, but there has been little research on safflower in the dryland region of the Pacific Northwest. Individual branches have 1 to 5 flower heads with 15 to 20 seeds/head. It grows to a height of 12 to 48 in and produce branches that are 18 to 30 in long.

Safflower is normally sown in April or early May and blooms and sets seed during periods of declining soil moisture and increasing temperatures in July and August. Despite these conditions, yields of 2,575 to 3,135 lbs/acre have been reported under commercial production in higher rainfall areas. Safflower has a long taproot (up to 10 ft) which enables it to extract water from deep in the subsoil. As a result, safflower is considered the most heat and drought tolerant of the alternative agronomic crops commercially available (Kephart et al. 1990). These properties may make safflower suitable for production in eastern Oregon. Safflower was first grown at the Sherman Station in 1940 (Oveson et al., 1940) and has been grown periodically in the PNW for the past 30 years (Auld et al. 1987c, Hang et al. 1982, Murray et al. 1981).

Safflower is a versatile crop; it can be grown as a source of edible oil, meal, whole seed for dairy cattle, birdseed, and oil for high-value industrial uses such as non-yellowing paints, alkyd resins in enamels, caulks, and putties, and as a biodiesel feedstock (Meka et al 2007). Safflower also makes an acceptable livestock forage if cut at or just after bloom stage. Because of its high linoleic acid content, safflower commands a premium price among edible oils, and is competitive with canola and olive oil. Cultivars high in oleic acid have also been bred.

Safflower is typically seeded in April or early May when soil temperatures are above 45ºF. Seedlings emerge in 1 to 3 weeks and early development is slow and the seedlings may spend 2 to 3 weeks in the rosette stage. At this stage safflower will tolerate temperatures as low as 20ºF but it is susceptible to frost injury from stem elongation to maturity.

The crop is seeded in 6- to 20-inch rows at about 20 lbs/acre resulting in 130,000 plants/acre; narrower rows are better for weed competition. Seed size varies depending on the variety and cropping conditions. The recommended seeding depth is 1 to 1.5 inches but not more than 2 inches. Safflower emergence is sensitive to soil crusting.

Diseases that affect safflower include *Alternaria* blight spotting disease, *Sclerotinia* head rot, damping off, rusts, and white mold. Weeds have proven to be a formidable challenge in our field trials. Early in the growth cycle, safflower is a poor competitor with weeds. The slow germination coupled with the 2-3 weeks in the rosette stage permits weeds to out-compete the crop. Grassy weeds can be problematic at this stage. Trifluralin applied pre-plant and incorporated will control some grass and broadleaf weeds; be sure to read and follow all pesticide labels. Wireworms, cutworms, and lygus bugs infest safflower.

Safflower requires approximately 2200 growing heat units and 120 frost-free days from planting to harvest. The crop is harvested directly when crop is at 9 to 13% moisture, about one to two months after flowering and when most leaves have turned brown; seeds should rub freely from the heads. Bird damage may be a problem.

In rotation, standing safflower stubble provides excellent snow trapping for good soil and water conservation in combination with other conservation practices. Safflower has a dense, root structure that can improve tilth and porosity by breaking up restrictive layers that develop in the soil. The crop, however, dries up soil for next crop; therefore, rotations should be carefully planned to reduce the impacts of a dry soil profile following safflower on the subsequent crop. Do not follow safflower with sunflowers, peas, lentils, canola and mustard because they suffer from same diseases. Safflower is one of the few crops that has been found to suppress root lesion nematodes which infest winter and spring cereal crops.

Development of safflower with sufficient winterhardiness to permit fall seeding would offer additional benefits to growers. Fall seeding is likely to result in increased yield compared to spring seedling, similar to the yield advantage of fall seeded wheat over spring seeded wheat. R.C. Johnson (personal communication) has found facultative safflower lines that can be seeded in the fall and are able to survive during the winter at Pullman, WA.

The objective of this field research was to evaluate the yield potential of spring and fall sown safflower in the low and intermediate rainfall zones in northeastern Oregon.

Materials and methods

Field trials were established at the Pendleton and Sherman Stations of the Columbia Basin Agricultural Research Center. The trials were seeded using a Hege small plot drill under

conventional tillage and a Fabro small plot no-till drill under direct seeding. The seeds were placed about one inch deep in the soil. Individual plots were 5 ft wide by 20 ft long in the conventional trials and 8 ft wide by 30 ft long in the direct seed trials. The trials were fertilized based on soil test information using the fertilizer rates recommended for spring wheat. The spring seeded trials were seeded in April while the fall trials were seeded in September and October with a dormant seeding in mid-February and spring seeding in early April. Weeds were controlled by hoeing as needed. The trials were harvested using a Hege small plot combine when the heads were sufficiently dry to permit efficient threshing, samples were weighed to estimate yield, and the oil content was measured by nuclear magnetic resonance spectroscopy.

Results and discussion

Field trials to evaluate the yield potential of potential alternate crops were conducted at Pendleton and Moro from 2002 to 2004 (Figs. 1-3). Spring sown safflower grain yields varied from 500 to 1100 lbs per acre, more than most other crops evaluated. Oil content of the seed was not measured in these trials.

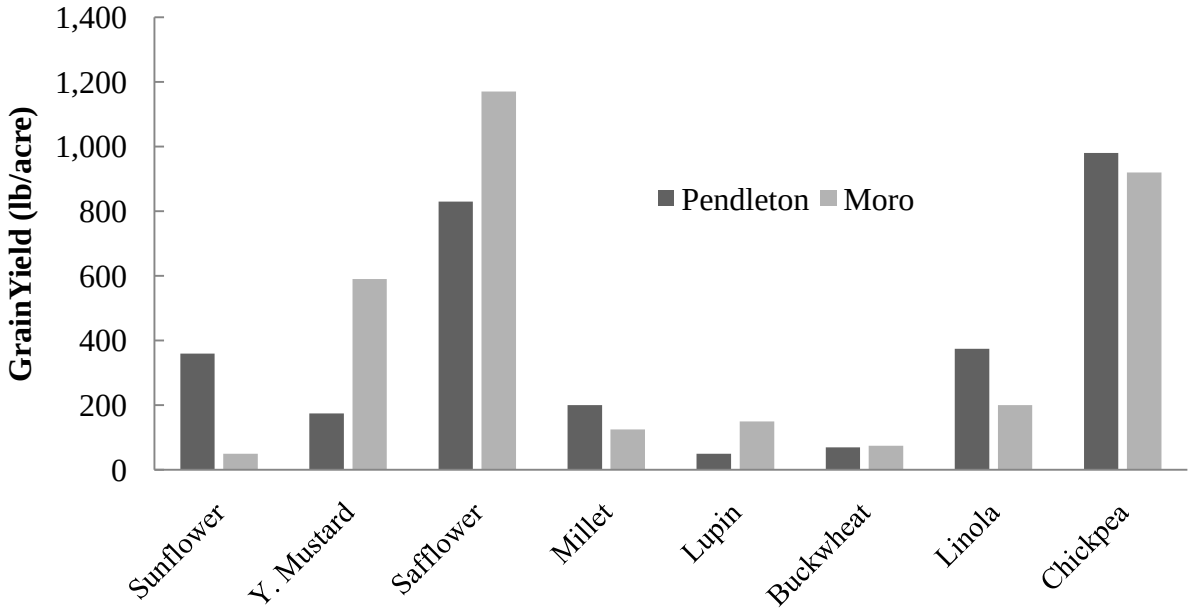

Figure 1. Yield of eight alternate crops at Pendleton and Moro, OR, 2002.

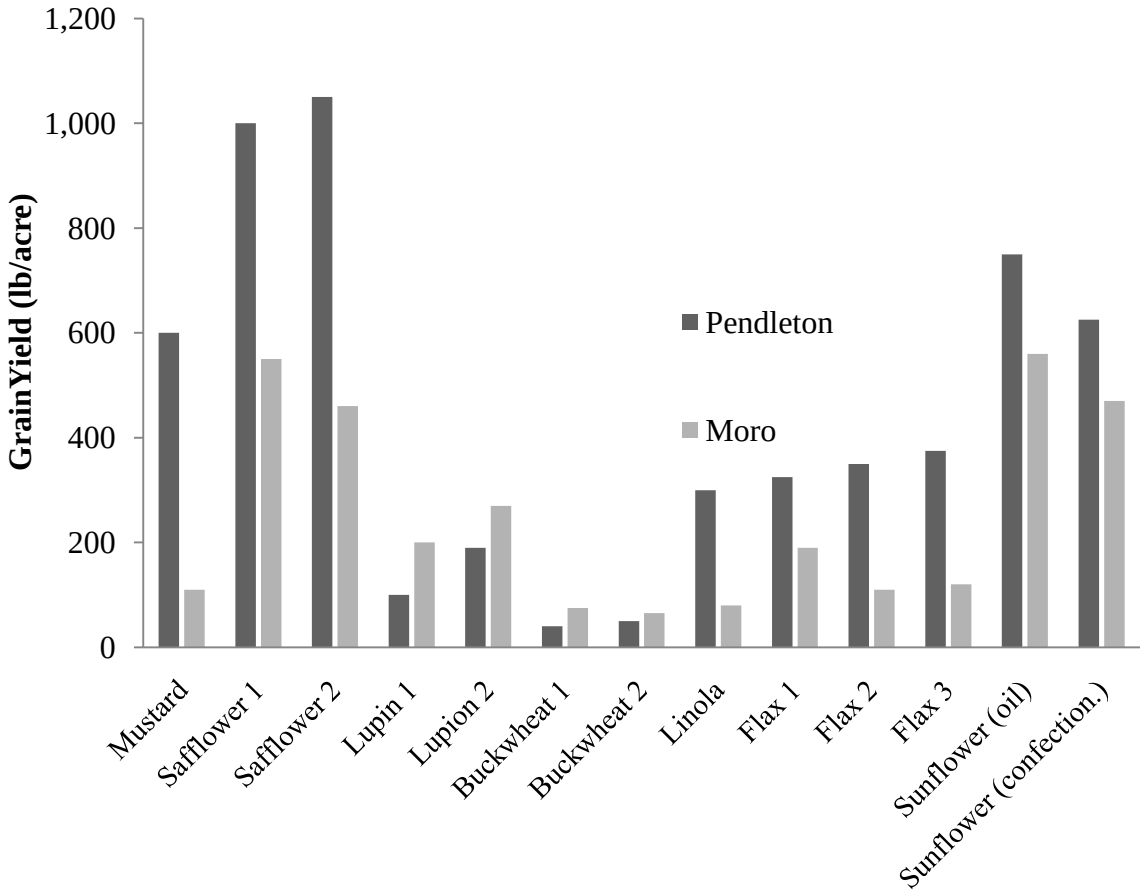

Figure 2. Yield of eight alternate crops at Pendleton and Moro, OR, 2003.

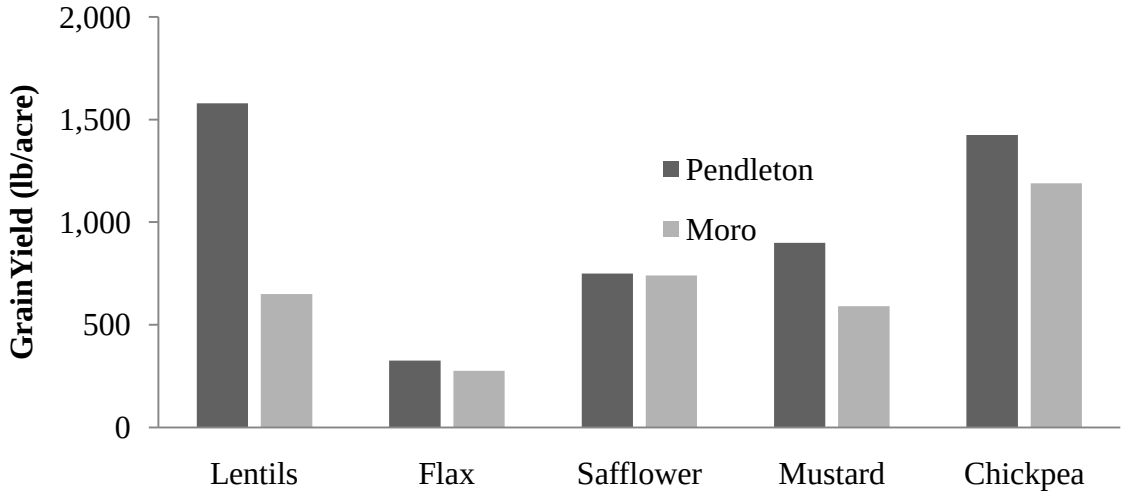

Figure 3. Yield of five potential alternative crops at Pendleton and Moro, OR, 2004.

Cultivar comparison

In further studies conducted in 2007 and 2008, spring sown safflower yields ranged from 400 to 1400 lbs/acre (Table 1-3). In these studies 15 cultivars were evaluated in 2007 and 17 in 2008, under both conventional tillage and direct seeded conditions. On average, safflower took 89 days to flower in 2007 and 102 days in 2008. Plants were mature at an average of 131 and 146 days at Pendleton in 2007 and 2008. The respective numbers for 2007 and 2008 were 87 and 106 days to flower and 143 and 148 days to mature at Moro.

At Pendleton, most cultivars yielded less under conventional tillage than under direct seeding in re-crop situations in 2007 (Table 1). The overall average yield was 642 lbs/acre under conventional tillage compared to 773 lbs/acre in direct seeding. Seeding on April 12 compared to April 26 resulted in greater yield of most cultivars except 'Hybrid 16' which exhibited increased yield at the later seeding date. For other cultivars, such as CW 990L, seeding date did not make a difference in yield. Cultivars 1133, 9262, CW 990L, Oleic 5, and S 345 were among the highest yielding cultivars.

At Moro, yields of all cultivars were increased when grown after chemical or conventional tillage fallow rather than after a previous crop in 2007 (Table 2). The average yield was 620 lbs/acre grown after a previous crop compared to 1,030 lbs/acre grown after chemical fallow and 935 lbs/acre grown after tillage fallow. The cultivars 1133, CW 1221, CW 74, S 345, and S 719 produced high yields under all cropping systems. The cultivar CW 4440 produced the lowest yields under all tillage systems and seeding dates at both locations and thus it is not recommended for this region.

In 2008, grain yields of most cultivars were higher at Pendleton following wheat under direct seeding than at Moro following chemical fallow (Table 3). Cultivars CW 1221, CW 2889, CW 880L, CW 990L, Hybrid 16, and S 3151 produced the highest yields across the two sites and CW 4440 produced the lowest yields at both locations.

Seed oil content of safflower generally ranges from 30 to 45%. White seeded varieties produce oil high in linoleic acid (polyunsaturated fats). The bird market prefers white seeded varieties. Striped seeded varieties produce high oleic acid that is preferred by the Japanese market. Results from safflower cultivar evaluation studies at Pendleton and Moro in 2007 and 2008 show oil content to vary from about 37 to 47%. Nutrasaff and 1132 had higher oil concentration than other cultivars at both sites and in both years. The total amount of oil per acre, however, is determined by seed yield and the oil concentration. Because the percent oil content of all the cultivars was similar, cultivars that produced high yields also produced the most oil per acre.

Table 1. Yield and oil concentration of spring sown safflower at Pendleton, 2007

Cultivar	Direct Seed Recrop, Sown April 12		Conventional Tillage Recrop, Sown April 12		Conventional Tillage Recrop, Sown April 26		Mean oil conc.
	Yield	Oil conc	Yield	Oil conc	Yield	Oil conc	
	lbs/acre	(%)	lbs/acre	(%)	lbs/acre	(%)	(%)
1133	883	42.0	723	41.5	527	40.0	41.2
9262	878	37.2	671	37.2	529	35.0	36.5
CW 1221	751	40.8	707	40.1	549	39.4	40.1
CW 2889	692	40.5	684	38.8	564	37.3	38.9
CW 4440	520	38.3	396	36.4	410	36.2	37
CW 74	789	39.2	839	39.0	618	37.8	38.6
CW 880L	802	38.7	617	38.1	558	37.5	38.1
CW 990L	854	39.8	751	39.8	694	41.4	40.4
Hybrid 16	731	37.1	599	36.9	813	37.4	37.1
Montola 03	667	38.3	603	37.5	495	36.5	37.4
Nutrasaf	654	45.3	485	44.1	432	41.6	43.7
Oleic 5	861	40.8	743	39.7	591	39.9	40.2
S 344	798	39.2	491	38.1	630	39.0	38.7
S 345	870	39.6	620	40.2	543	39.1	39.6
S 719	852	39.9	698	38.7	609	39.2	39.3
Average	773		642		571		39.1
$LSD_{0.05}$	160		172		108		

Table 2. Yield and oil concentration of spring sown safflower at Moro, 2007

Cultivar	Direct seed re-crop, sown April 16		Chemical fallow, sown April 16		Conventional tillage fallow, Sown April 19		Mean oil conc.
	Yield lbs/acre	Oil conc (%)	Yield lbs/acre	Oil conc (%)	Yield lbs/acre	Oil conc (%)	(%)
1133	684	42.1	1,087	43.1	1,015	43.5	42.9
9262	655	37.1	1,052	39.4	926	37.9	38.1
CW 1221	588	40.5	1,196	42.9	1,036	42.4	41.9
CW 2889	580	41.1	1,005	42.4	1,018	41.5	41.7
CW 4440	378	38.2	491	37.7	561	38.1	38.0
CW 74	673	40.8	1,078	41.4	1,047	41.7	41.3
CW 880L	637	41.3	1,083	41.6	901	41.2	41.3
CW 990L	647	40.4	1,152	42.8	1,021	41.8	41.7
Hybrid 16	596	37.6	1,088	38.0	1,023	38.7	38.1
Montola 03	550	39.1	812	39.3	900	39.5	39.3
Nutrasaf	577	46.2	925	47.7	820	46.9	46.9
Oleic 5	754	41.0	984	42.3	908	42.2	41.8
S 344	584	40.2	1,053	41.4	997	41.4	41.0
S 345	723	41.1	1,256	42.4	823	42.0	41.8
S 719	678	41.3	1,192	41.3	1,043	41.2	41.3
Average	620		1,030		935		41.1
$LSD_{0.05}$	118		170		137		

Table 3. Yield and oil concentration of spring sown safflower at Pendleton and Moro, 2008

Cultivar	Direct Seed Recrop, Pendleton		Chemical Fallow, Moro	
	Yield	Oil Concentration	Yield	Oil Concentration
	lbs/acre	----- % -----	lbs/acre	----- % -----
CW 1221	1,487	38.5	1,157	42.6
CW 2889	1407	39.8	1,225	40.6
CW 4440	665	37.9	733	39.7
CW 74	1,257	40.3	1,015	40.8
CW 880L	1,432	41.6	1105	40.8
CW 990L	1450	41.0	1,273	41.6
Hybrid 16	1,421	36.9	1,346	40.4
Montola 03	1,118	40.4	1045	36.3
Nutrasaf	1,147	45.6	1,051	45.0
Oleic 5	1,352	41.3	1,185	38.0
S 344	1,343	41.6	1,004	41.2
S 345	1,320	41.9	1,048	42.8
S 719	1,193	41.5	1,105	41.7
S 2106	1,242	41.2	727	44.6
S 3151	1,448	39.6	1,407	41.8
ST 3538	-	-	1224	36.1
ST 7446	-	-	959	39.1
Average	1,285	40.6	1,094	40.3
$LSD_{0.05}$	261			

Fall seeding

Safflower lines with greater winterhardiness have been identified that may permit successful fall seeding. Fall sown safflower may offer the potential for earlier maturity and higher yields compared to spring seeding. Three separate yield potential trials were established in the fall and spring of 2007-08. Eight lines of safflower were seeded on September 15 and on April 1 in one trial, six safflower lines were seeded on October 15 and on April 1in a second trial, and five lines were seeded on February 1 and April 1in a third trial. The spring lines did not survive the winter when seeded in September or October, but they did survive when seeded in mid-February (Table 4). The winter-hardy lines were much more productive sown in the fall compared to when they were sown in the spring. The average yield of the cultivars sown on September 14, October 14, or February 14 was 552, 575, and 308 lbs greater than the same cultivars sown on April 1.

Yields were somewhat reduced in the 2008-09 crop compared to the 2007-08 crop. Fall seeding conditions were less favorable in 2008 and this delayed germination and stand establishment in the fall. Two of the spring lines sown on September 15 survived the winter, apparently protected from the coldest weather by snow cover, in contrast to the previous winter when all spring lines sown in the fall died in the winter. Fall sown plants were slightly shorter than the spring sown plants, but they generally produced greater yield (Table 5).

Table 4. Yield of fall and spring seeded safflower at Pendleton, 2007-08.

Cultivar	Habit	Early fall seeding		Mid-fall seeding		Dormant seeding	
		Sept. 14	April 1	Oct. 14	April 1	Feb. 14	April 1
		---------- lbs/acre ----------					
P1-C2	Winter	1,690	1,114				
P2-C2	Winter	1,720	1,215	1,967	1,254		
BJ27-C3	Winter	1,735	1,240	1,617	1,234	1,414	1,152
KN-144	Winter	1,910	1,030	1,804	1,191	1,140	1,117
CalOilWin	Winter	1,070	768	1,622	925	1,151	851
Gila	Spring	Died	880			1,441	885
Girard	Spring	Died	894	Died	1,325		
CalOilSp	Spring	Died	880	Died	1,132	1,209	810
Average*		1,625	1,073	1,725	1,150	1,271	963

*Average of cultivars that survived the winter.

Table 5. Yield of fall and spring seeded safflower at Pendleton, 2008-09.

Cultivar	Habit	Sept. 15		March 15	
		Plant ht.	Yield	Plant ht.	Yield
		In.	lbs/acre	In.	lbs/acre
P1-C2	Winter	26	1,086	28	1,193
P2-C2	Winter	25	1,402	27	1,141
BJ27-C3	Winter	26	1,282	28	856
KN-144	Winter	35	1,525	37	710
Lesaf 494	Spring	Died	Died	28	627
Gila	Spring	Died	Died	29	1,096
Girard	Spring	28	365	32	709
CalOilSp	Spring	30	1,368	31	838
Average*		28.3	1,171	30	907

*Average of cultivars that survived the winter.

In both 2007-08 and 2008-09, there was little or no winter kill among the winter hardy safflower lines. Minimum temperatures fell below 0° F in both years but there was adequate snow cover to protect the plants. We seeded several of the same lines in the fall of 2009-10, including P1-C2, P2-C2, BJ27-C3 and KN-144. During early December 2009, we experienced temperatures below 0° F with little or no snow cover and there was significant winter injury and very few plants survived. The fall seeding trials were abandoned and only the spring seeded trials were taken to harvest.

Summary and Conclusions

Safflower is a potential alternate crop that can successfully grown in the low and intermediate rainfall areas of eastern Oregon. The greatest yield of spring sown safflower was nearly 1,500 lbs/acre and greatest yield of fall sown safflower was 1,900 lbs per acre. Yields of winter-hardy safflower produced greater yields when sown in the fall rather than in the spring, although excessively cold winter temperatures without adequate snow cover resulted in excessive winter damage. Spring sown crops should be seeded as early as possible for the greatest yield. Additional research is needed to identify lines with greater winterhardiness, establish fertilizer recommendations, and develop effective weed control practices. Research into the use of pre-harvest desiccants to promote earlier harvest is also needed.

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