Agronomic Requirements of *Euphorbia lagascae:* A Potential New Drought-Tolerant Crop for Semi-Arid Oregon: 2008

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Background and Rationale

Euphorbia lagascae has been recognized as one of the more promising potential new industrial crops for temperate latitudes (Roseberg, 1996). In the late 1950s and early 1960s the USDA analyzed many plant species in search of novel chemical compounds. They first recognized that *E. lagascae* (Spreng.), Euphorbiaceae (euphorb or spurge family), was unique among the 58 euphorbs tested (and almost unique among all plants) in that the seed oil contained high levels of a C_{18} epoxy fatty acid (EFA) known as vernolic acid (12,13 epoxy-cis-9-octadecenoic acid) (Kleiman et al., 1965). *E. lagascae* (hereafter simply called 'euphorbia') is a drought-tolerant native of Spain whose seed contains about 45%-50% oil, of which 60%-65% is

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vernolic acid (Kleiman et al., 1965; Vogel et al., 1993). Vernolic acid is an EFA of great interest to the paint and coating industry as a drying solvent in alkyd resin paints, a plasticizer or additive in polyvinyl chloride (PVC) resins (Riser et al., 1962; Carlson et al., 1981; Carlson and Chang, 1985; Perdue, 1986), and possibly in pharmaceutical applications (Ferrigni and McLaughlin, 1984). Paints formulated with vernolic acid emit very low levels of volatile organic compounds (VOC) and thus using such paints would greatly reduce the VOC air pollution that now occurs with volatilization of alkyd resins in conventional paints (Brownback and Glaser, 1992; Anon, 1993). The Clean Air Act amendments of 1990 required the reduction of VOC pollutants, and regulations in California have been implemented earlier with greater effect upon the paint industry.

After initially discovering euphorbia's valuable and nearly unique seed oil, the major problem that hindered both breeding and agronomic research needed to develop euphorbia as a crop has been its violent seed shattering habit, combined with its indeterminate flowering and seed habit, making it difficult both to harvest and to measure seed yield. No wild accessions of euphorbia contain a non-shattering trait (Vogel et al., 1993; Pascual-Villalobos et al., 1994). However, in the early-1990s, chemically induced, non-shattering mutants were developed in Spain (Pascual and Correal, 1992; Pascual-Villalobos et al., 1994; Pascual-Villalobos, 1996). These non-shattering seeds were transferred to Oregon State University in the mid-1990s and formed the basis for research conducted at the Southern Oregon Research & Extension Center (SOREC) and the Klamath Basin Research & Extension Center (KBREC) on a sporadic basis starting in 1995.

Euphorbia is highly self-fertile, with pollen transfer occurring before insects can access the floral organs (Vogel et al., 1993). Therefore, outcrossing should be limited. We have observed that, because of its apparent tolerance to drought and heat, euphorbia appears to prefer a warm growing season and very dry conditions during seed maturation, or else it tends to remain green and continue growing. Due to the presence of latex and other potentially irritating compounds in the stems and petioles, it will be important to understand which safety precautions are necessary during harvest and processing (Turley et al., 2000). Processing chemistry and product development should continue on a larger scale as more seed becomes available.

Competing Sources of Epoxidized Fatty Acids

Very few plants naturally produce high levels of vernolic acid in their seed oils (Kleiman, 1990) and most of those have significant barriers to domestication and agronomic production (Earle, 1970). For example, early on, two other euphorbs (*Cephalocroton cordofanus* and *Cephalocroton peuschelii*) were shown to contain high levels of vernolic acid. However, because they are both perennial shrubs their potential for cultivation was deemed less than that of euphorbia, an annual. General consensus is that the three vernolic acid-producing species that appear to have the best chance for domestication are *Euphorbia lagascae* (Kleiman et al., 1965), *Vernonia galamensis* (Carlson et al., 1981; Perdue et al., 1986), and Stokes aster [*Stokesia laevis*] (Earle, 1970; Campbell, 1981). Previous field observations suggest that euphorbia is the most drought-tolerant of these three species.

Current sources of EFAs include epoxidized soybean oil, linseed oil (from oilseed flax), and processed petrochemicals (Carlson and Chang, 1985; Perdue et al., 1986; Dierig and Thompson, 1993). However, epoxidation of simple vegetable oils is an expensive process, and petrochemicals are a non-renewable and increasingly imported raw material. The US typically uses over 30,000 tons of EFAs in over 250 million gallons/year of paints and coatings alone (Anon, 1989). In addition, epoxidation of simple oils such as soybean oil results in carbon chains with the epoxide group appearing at various points along the chain. Vernolic acid produced by plants, however, always has the epoxide group on the same carbon atom within the chain, leading to unique and improved properties (Trumbo, 1998).

Crop Status

There is no commercial acreage of euphorbia at present. Research interest and activity has continued both in the US and in Europe on a sporadic basis (Turley et al., 2000). Because of its unique oil properties, it is difficult to predict exact prices and potential grower profits. However, by using epoxidized soybean oil as a surrogate, a value can be roughly calculated for a hypothetical euphorbia crop.

Average monthly prices for US soybean oil ranged from $0.19 to $0.62/lb between 1992 and 2008, usually above $0.30/lb in recent years. Based on a soybean oil price of $0.30/lb, and assuming the value would double or triple after conversion to an EFA (Perdue et al., 1986), an already existing EFA such as euphorbia oil would be worth at least $0.60 to $0.90/lb after crushing, or $0.30 to$0.45/lb of seed (assuming 50% seed oil content). This value range has been confirmed in discussions with industry personnel. Obviously there are costs associated with crushing and purifying the raw euphorbia oil after harvest, but even if the farmer received only half of the oil's market value for the harvested seed, a seed yield of 1000 lb/ac could return $150-$275/ac to the grower at these conservative prices. This calculation does not factor in the potential higher value of euphorbia oil compared to epoxidized soybean oil due to euphorbia oil's greater chemical functionality. Because it seems likely that euphorbia could be grown with reduced input costs compared to other crops, its net return to the farmer would likely be much greater than other crops having similar gross returns.

Comparison with Related Species

When evaluating the agronomic requirements of potential new crops such as euphorbia, it is helpful to review what is known about related species in terms of their biology, growth and yield potential, current human uses, and response to potential management practices such as chemical weed control.

Although the genus *Euphorbia* includes over 1,600 species, very few are cultivated or used by humans, and those that are used are typically grown as ornamentals or are harvested from wild stands. Examples of the few euphorbs used by humans include: candelilla (*E. antisyphilitica*), collected in the wild for the hard wax on its surface, and formerly used to treat the disease syphilis; wild ipecac (*E. ipecacuanhae*), used medicinally; and poinsettia (*E.*

pulcherrima), an ornamental flower commonly used as a decoration during the Christmas holiday (Bailey, 1976).

Even within the much broader Euphorbiaceae (spurge) family, relatively few species are used by humans. Of the nearly 300 genera in this family, less than 30 contain species that are used by humans, and in almost every case the plant is cultivated only as an ornamental garden plant. The few exceptions that are cultivated for other productive uses include the following genera: *Aleurites* (tung oil tree); *Hevea* (rubber tree); *Manihot* (roots used to make manioc, tapioca, and cassava foods); and *Ricinus* (castor bean oil).

In most cases, however, human use of euphorb species is mainly limited to exploiting wild plant stands, although some intentional cultivation may occur in local areas. Examples of such uses include species within the following genera: *Antidesma* and *Phyllanthus* (edible fruit for preserves); *Croton* and *Joannesia* (oil for varnish or purgative); *Bischofia* and *Putranjiva* (hardwood timber); and *Garcia* and *Sapium* (drying oils and rubber) (Bailey, 1976). These crops are trees and/or are not commonly grown in North America, and thus information regarding their growth requirements and response to agronomic practices is limited, and would not be applicable in this region even if available.

Certain species of the *Euphorbia* genus are serious weeds in the western US, especially in areas of limited moisture. These weeds include: leafy spurge (*E. esula*); prostrate spurge (*E. humistrata*); spotted spurge (*E. maculata*); and nodding spurge (*E. nutans*). Fortunately, our previous studies with *E. lagascae* show that it is susceptible to several common broadleaf herbicides, and does not appear to persist or spread in or near fields where it has been grown (Roseberg, 2000a; Roseberg, 2000b; Roseberg, 1998).

Goal of Current Studies

Due to euphorbia's apparent drought tolerance, the potential of growing euphorbia under minimal irrigation on less-productive soils could help reduce water use conflicts in the Klamath Basin and other areas of the arid and semi-arid western US. Thus, given both the potential of euphorbia as a drought-tolerant crop, and the encouraging data from previous studies at SOREC near Medford, OR (Roseberg, 1999; Roseberg et al., 1997a; Roseberg et al., 1997b), we decided to proceed with additional, more detailed agronomic studies at additional sites in southern Oregon over multiple years, beginning in 2008.

The objective of these studies was to examine euphorbia's response to differences in seeding date, irrigation rate, nitrogen fertilization, plant density, and cultivar in semi-arid southern Oregon. In 2008 these studies were duplicated at two locations to compare responses in two dramatically different climates (Medford and Klamath Falls, OR). Excess seed produced from these studies was supplied to USDA-ARS-NCAUR lab in Peoria, IL for chemical processing tests.

Procedures

Studies were conducted at KBREC and SOREC. Weather data was collected at the nearby US Dept. of Reclamation Agricultural Meteorological (AgriMet) weather stations located at both KBREC and SOREC. (US Bureau of Reclamation, 2008). The AgriMet site calculates Penman evapotranspiration for each site based on the weather data.

At each location four separate experiments were conducted: I) Seeding date by cultivar; II) Nitrogen fertilizer rate by irrigation rate; III) Row spacing by cultivar; IV) Seeding date by irrigation rate. Where irrigation rate was a variable, there were three irrigation treatments (‘high’, ‘low’, and ‘none’) at each location. At KBREC, one irrigation was applied soon after seeding due to extreme soil dryness and to simulate effects of a normal spring rain event (followed by minimal precipitation and no irrigation for the remainder of the summer). Where seeding date was a variable, there were two seeding dates at each location. For each trial we used cleaned seed saved from previous agronomic studies.

Kincaid Plot Drill

The euphorbia seed was drilled to a depth of 0.25 inch using a tractor-mounted modified Kincaid (Kincaid Equipment Mfg.) three row plot drill (rows spaced 24-inches apart), except for the row spacing trial which was seeded by hand using a Planet Junior single row seeder. All plots seeded with the Kincaid drill were seeded at a rate of 30 seeds/ft^2. The Planet Junior hand-seeder was adjusted to drop seeds at a similar rate in those plots. During the growing season weeds were controlled by mechanical and manual cultivation. No fertilizer was applied except for in the nitrogen rate by irrigation rate experiment. At maturity, all plots were harvested with a Hege (Hans-Ulrich Hege) plot combine. Harvested seed was cleaned using a Clipper seed cleaner and the percentage of good seed, partial pods and whole pods were calculated. After the seed was cleaned, good seeds were analyzed for oil content by the USDA-ARS-NCAUR lab in Peoria, IL, and oil yield per acre was calculated after correcting for the proportion of good seed within the partial pods and whole pods by weight.

All measured parameters were analyzed statistically using SAS® for Windows, Release 9.1 (SAS Institute, Inc.) software. Analysis of variance was calculated according to the appropriate individual experiment's design. Treatment significance was based on the F test at the P=0.05 level. If this analysis indicated significant treatment effects, least significant difference (LSD) values were calculated based on the student's *t* test at the 5% level.

I. Seeding Date by Cultivar Studies

Materials and Methods

KBREC

This study was conducted within the 'low' irrigation treatment and was set up as a split plot design with seeding date as the main plot and cultivar as the subplot. The cultivars Eu005, Eu006, and Eu008 were used. The two seeding dates were May 9 and June 2. A total of 5.9 inches of irrigation was applied during the growing season in addition to 2.6 inches of rainfall (Table 1). The calculated Penman evapotranspiration during the growing season was 26.0 inches. The first seeding date was harvested on September 24 and the second seeding date was harvested on October 23.

SOREC

This study was laid out using the same design as the KBREC study. The two seeding dates were May 1 and May 27. A total of 16.8 inches of irrigation was applied during the growing season in addition to 1.9 inches of rainfall (Table 1). Calculated Penman evapotranspiration during the growing season was 30.1 inches. The first seeding date was harvested on September 25 and the second seeding date was harvested on October 16.

Results and Discussion

KBREC

There was no significant difference in seed yield or oil yield between seeding date or cultivar treatments (Table 2). Although 2008 was the first year euphorbia was tested at KBREC, seed yields were lower than in some previous experiments at SOREC.

There was no significant difference in oil content between cultivars but there was a significant difference in oil content between seeding dates. For each cultivar the oil content was greater for the June 2 seeding date than for the May 9 seeding date. The percent whole pods measurement is an indication of the maturity and relative indehiscence of the plants at time of harvest. There was no significant difference in percent whole pods for seeding date but there was a significant difference in percent whole pods between cultivars. For both seeding dates, the cultivar Eu005 had lower percent whole pods indicating somewhat earlier maturity and/or easier threshing than the other two cultivars.

SOREC

Overall seed yield was lower at SOREC in 2008 than in some previous experiments there. There was no significant difference in seed yield between cultivars or seeding dates although there was a tendency for increased seed yield for the May 27 seeding date (Table 3). There was no significant difference in oil content between seeding dates or cultivars. Thus, there was no significant difference in oil yield between seeding dates or cultivars, resulting in an oil yield pattern similar to the seed yield pattern between treatments. There was a significant difference in the percent whole pods between cultivars and between seeding dates. In general, the later seeding date (May 27) had higher percent whole pods than the earlier seeding date (May 1), suggesting that euphorbia seeded later were not as mature at harvest time. As was true at KBREC, the cultivar Eu005 had a lower percentage of whole pods for both seeding dates, suggesting earlier maturity and/or easier threshing. In previous trials at SOREC, seeding as early as March resulted in increased seed yields. In 2008, we were not able to test the effects of early spring seeding dates on seed yield at either location.

II. Irrigation Rate by Nitrogen Rate Studies

Materials and Methods

KBREC

This study was laid out as a split plot design with irrigation rate as the main plot and nitrogen rate as the subplot. There was only one seeding date (May 9). The nitrogen fertilizer treatments were applied on June 4, and consisted of 0, 60, 120, and 180 lb/ac of N as urea. During the growing season the ‘high’ treatment received 9.0 inches of irrigation, the ‘low’ treatment received 5.9 inches of irrigation, and the ‘none’ treatment received 2.4 inches of irrigation (Table 1). The KBREC site received 2.6 inches of rainfall during the growing season. The calculated Penman evapotranspiration during the growing season was 26.0 inches. This study was harvested on September 24.

SOREC

The study was laid out in the same design and with the same treatments as KBREC. It was seeded on May 1. At SOREC, the ‘high’ treatment received 20.4 inches of irrigation, the ‘low’ treatment received 16.8 inches of irrigation, and the ‘none’ treatment did not receive any irrigation during the growing season. This site received 1.9 inches of rainfall during the growing season. The calculated Penman evapotranspiration during the growing season was 30.1 inches.

The ‘high’ and ‘low’ irrigation treatments were harvested on September 25, but the ‘none’ treatment was not harvested until October 16 due to later maturity.

Results and Discussion

KBREC

There was no significant difference between nitrogen rate treatments for seed yield, oil content, oil yield, or percent whole pods (Table 4). The only significant difference between irrigation rates occurred for oil content, although the differences between irrigation rates for seed yield and percent whole pods were nearly significant at the $P = 0.05$ level. The highest oil content values occurred in the ‘none’ irrigation treatment. Although differences were not significant, seed yield and percent whole pods tended to the highest in the ‘low’ irrigation treatment.

SOREC

Unlike the results at KBREC, there were statistically significant differences for several parameters for both irrigation rate and nitrogen rate at SOREC (Table 5). Seed yields were reduced under non-irrigated conditions. As occurred at KBREC, the highest oil content values occurred in the ‘none’ irrigation treatment. Percent whole pods were reduced in the ‘high’ irrigation treatment. This was similar to the pattern observed at KBREC, but was more pronounced at SOREC. This result was a bit surprising, as we expected that plants grown under drought stress would shatter more easily than those grown under more irrigation. However, it may be that plants grown under drought stress actually retain the seed pods against shattering more strongly than those grown under less stressful conditions of high irrigation. Despite the increased oil content in the non-irrigated treatment, oil yield followed nearly the same pattern as seed yield, resulting in significantly lower oil yields in the non-irrigated treatment area. Although the difference between nitrogen rates was statistically significant for seed yield, the pattern did not seem to follow any known typical plant response. For the ‘high’ and ‘low’ irrigation treatments, the highest seed yield occurred where no nitrogen fertilizer was applied. Likewise, the difference in oil content between nitrogen treatments was significant, but the only clear pattern was that the high nitrogen rate resulted in the lowest oil content for the ‘high’ and ‘low’ irrigation treatments.

III. Row Spacing by Cultivar Studies

Materials and Methods

KBREC

This study was conducted within the 'low' irrigation treatment and was laid out as a factorial design with cultivar and row spacing as the two factors. The three cultivars (Eu005, Eu006, and Eu008) were seeded on May 9 using the Planet Junior single row seeder at a rate equal to the experiments seeded with the Kincaid drill if expressed as the number of seeds per foot of row. For this study, three row spacings were used: 12 inches, 24 inches, and 36 inches between rows. Thus, when the seeding rate was expressed as seeds/ft^2, the 12 inch row spacing plots had twice as many seeds (60 seed/ft^2) as plots seeded with the Kincaid drill in the other studies since the Kincaid drill had a 24 inch row spacing. Similarly, the 'per-area' seeding rate for the 36 inch row spacing treatment was two-thirds (20 seeds/ft^2) that of the other studies where the Kincaid drill was used. Plots were harvested September 24.

SOREC

This study was laid out and seeded using the same equipment and design as the KBREC study. Plots were seeded on May 1 and harvested September 25.

Results and Discussion

KBREC

There was no significant difference between cultivars for seed yield, oil content, oil yield, or percent whole pods (Table 6). There was also no significant difference between row spacing treatments for oil content and percent whole pods. There was a significant difference in seed yield between row spacing treatments, but this difference was only apparent for the Eu006 and Eu008 cultivars, where the widest row spacing resulted in the highest seed yield. There was also a significant difference in oil yield between row spacings, which tended to follow the same pattern as the seed yield, were the widest row spacing resulted in the highest oil yield for the same two cultivars.

SOREC

Seed yields at SOREC tended to be quite a bit higher than the comparable study at KBREC. Unlike the results at KBREC, there was no significant difference between cultivars or row spacing for seed yield, oil content, or oil yield (Table 7). However, differences between row spacing and cultivar were both significant for percent whole pods. Percent whole pods was greatest at the widest row spacing, and at each row spacing the percent whole pods for the Eu005 cultivar was less than for the other two cultivars. These results suggest that euphorbia is very elastic in nature and will form a larger plant with more branches when seeded at wider spacing but will result in a more upright plant with fewer branches (but more concentrated seed density per plant) at narrow row spacings.

IV. Irrigation Rate by Seeding Date Studies

Materials and Methods

KBREC

This study was set up as a split plot design with the three irrigation rates as the main plots and two seeding dates as the subplots. The three irrigation rates were the same as those in the irrigation rate by nitrogen rate study (Study II described above). The two seeding dates were May 9 and June 2. The first seeding date was harvested on September 24 and the second seeding date was harvested on October 23.

SOREC

This study was set up as a split plot design in the same manner as the KBREC study, and the three irrigation rates at SOREC were the same as those in the irrigation rate by nitrogen rate study (Study II described above). The two seeding dates were May 1 and May 27. The first seeding date was harvested on September 25 and the second seeding date was harvested on October 16.

Results and Discussion

KBREC

Seed yields were fairly low overall in this experiment at both sites. There was not a significant difference between irrigation rates for seed yield, oil yield, or percent whole pods (Table 8). There was a significant difference between irrigation treatments for oil content. As irrigation rate increased, oil content decreased. There was a statistically significant difference between seeding dates for all measured parameters, including seed yield, oil content, oil yield, and percent whole pods. Seed yield was greater for the earlier seeding date under the ‘high’ and ‘none’ irrigation treatments. However, seed yield was greater for the later seeding date for the ‘low’ irrigation treatment. Oil content was greater for the later seeding date in each case. Despite these differences in oil content, the overall oil yield followed the same pattern as seed yield: Oil yield was greatest for the early seeding date in the ‘high’ and ‘none’ irrigation treatments, but oil yield was greatest for the later seeding date in the ‘low’ irrigation treatment.

SOREC

There was a significant difference in seed yield between irrigation treatments (Table 9). Seed yields were higher in the ‘low’ irrigation treatment than the ‘high’ irrigation treatment, which in turn was significantly higher than the ‘none’ treatment. There was not a significant difference in oil content or percent whole pods between irrigation treatments. There was a significant difference in oil yield between irrigation treatments, following the same pattern as the differences in seed yield.

There was a significant difference in all parameters measured due to seeding date. The earlier seeding date resulted in a greater seed yield for all irrigation treatments. There was not a significant difference in oil content between the two seeding dates under the ‘high’ irrigation treatment, however the earlier seeding date did result in higher oil content for the ‘low’ and ‘none’ irrigation treatments. Despite these differences in oil content, the differences in oil yield between seeding dates retained the same pattern as the differences in seed yield for all three irrigation rates. The percent whole pods was greater at the later seeding date for all three irrigation treatments, suggesting that plants from the later seeding date did not mature as much as those from the earlier seeding date by harvest time.

Overall Conclusions

Euphorbia is very flexible, and can adapt to many different growing conditions. These experiments confirm that euphorbia is able to survive and produce a harvestable seed yield under completely non-irrigated conditions, but that seed yield is enhanced by some irrigation. Earlier seeding dates tended to result in greater seed yield and earlier maturity, and the interactions between irrigation and seeding date were amplified under hotter, drier conditions, such as those experienced at SOREC compared to KBREC.

There was very little difference between the cultivars, however Eu005 seemed to mature slightly sooner than the others. There was no observable benefit from nitrogen fertilization.

As a general rule, oil content was increased under conditions of greater stress, such as less irrigation or later seeding date. However, these differences in oil content were usually not large enough to affect the overall oil yield, which was primarily controlled by the seed yield.

The interaction between a main plot treatment and the subplot treatment was significant in only a few cases. The only case where the main plot treatment and the subplot treatment were both statistically significant and where the interaction between the two factors was also statistically significant occurred for oil content in the irrigation rate by nitrogen fertilizer rate trial at SOREC (Table 5). In this case, oil content was higher under the ‘none’ irrigation treatment for some nitrogen rates, but oil content response to nitrogen fertilizer did not respond the same from one irrigation treatment to another.

Evaluating earlier seeding dates in combination with irrigation treatments would be helpful in order to better understand the limits of seeding date and irrigation response for euphorbia seed production in southern Oregon. In these studies, row spacing did not have a strong effect on seed yield or quality. At times in the past, euphorbia has produced greater seed yields at narrow row spacings, and at other times seed yield is increased at wider row spacings; a condition resulting in larger, branchier plants. It would be useful to test euphorbia under a range of seeds/ft^2 and constant row width to see whether seed density within a row or row spacing are the factors that contribute to these differences in growth habit and yield.

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Table 1. 2008 Precipitation & irrigation for euphorbia variety x irrigation rate trials.

Klamath Basin Research & Extension Center, Klamath Falls, OR.							
		"High" Block		"Low" Block		"None" Block	
Month	Precipitation (inch)	Irrigation (inch)	Irrigation Applications	Irrigation (inch)	Irrigation Applications	Irrigation (inch)	Irrigation Applications
May	1.68	2.40	1	2.40	1	2.40	1
June	0.66	3.60	3	1.20	1	0.00	0
July	0.03	2.04	2	1.32	1	0.00	0
August	0.20	0.96	1	0.96	1	0.00	0
September	0.00	0.00	0	0.00	0	0.00	0
Total	**2.57**	**9.00**	**7**	**5.88**	**4**	**2.4**	**1**
Southern Oregon Research & Extension Center, Medford, OR							
May	1.74	6.00	4	6.00	4	0.00	0
June	0.08	5.20	4	3.60	3	0.00	0
July	0.00	6.00	4	5.20	3	0.00	0
August	0.12	3.20	2	2.00	1	0.00	0
September	0.00	0.00	0	0.00	0	0.00	0
Total	**1.94**	**20.40**	**14**	**16.80**	**11**	**0.00**	**0**

Table 2. 2008 Euphorbia seeding date x variety trial.
Klamath Basin Research & Extension Center, Klamath Falls, OR.

Seeding Date	Cultivar	Seed Yield (lb/ac)	Rank	Percent Whole Pods	Rank	Oil Content (%)	Rank	Oil Yield (lb/ac)	Rank
May 9	Eu005	168	4	14.0	6	42.8	5	73	4
	Eu006	122	6	18.0	2	40.9	6	52	6
	Eu008	147	5	14.6	4	43.6	4	63	5
June 2	Eu005	190	2	14.6	5	48.9	1	93	2
	Eu006	179	3	16.8	3	47.8	3	87	3
	Eu008	214	1	21.9	1	48.2	2	104	1
Mean		170		16.6		45.4		79	
***P* (Seeding Date)**		**0.430**		**0.186**		**0.009**		**0.283**	
LSD (0.05)- Seeding Date		NSD		NSD		3.7		NSD	
CV Seeding Date (%)		100.8		26.2		9.4		99.8	
***P* (Cultivar)**		**0.651**		**0.033**		**0.079**		**0.572**	
LSD (0.05)- Cultivar		NSD		3.0		NSD		NSD	
CV Cultivar (%)		51.8		21.5		3.9		48.1	
***P* (Seeding Date X Cultivar Interaction)**		**0.814**		**0.023**		**0.302**		**0.787**	

Table 3. 2008 Euphorbia seeding date x variety trial.
Southern Oregon Research & Extension Center, Medford, OR.

Seeding Date	Cultivar	Seed Yield (lb/ac)	Rank	Percent Whole Pods	Rank	Oil Content (%)	Rank	Oil Yield (lb/ac)	Rank
May 1	Eu005	123	5	2.6	6	49.5	1	63	5
	Eu006	90	6	6.0	4	48.4	4	44	6
	Eu008	145	4	5.2	5	48.5	3	68	4
May 27	Eu005	252	1	7.5	3	49.0	2	124	1
	Eu006	238	2	11.4	2	46.6	5	110	2
	Eu008	176	3	14.4	1	45.4	6	79	3
Mean		171		7.8		47.9		81	
***P* (Seeding Date)**		**0.090**		**<0.001**		**0.088**		**0.091**	
LSD (0.05)- Seeding Date		NSD		1.3		NSD		NSD	
CV Seeding Date (%)		85.9		19.4		5.3		81.7	
***P* (Cultivar)**		**0.753**		**<0.001**		**0.065**		**0.564**	
LSD (0.05)- Cultivar		NSD		1.8		NSD		NSD	
CV Cultivar (%)		56.8		27.7		5.0		58.2	
***P* (Seeding Date X Cultivar Interaction)**		**0.307**		**0.049**		**0.422**		**0.302**	

Table 4. 2008 Euphorbia nitrogen rate x irrigation rate trial.
Klamath Basin Research & Extension Center, Klamath Falls, OR.

Irrigation Rate	Nitrogen Rate	Seed Yield (lb/ac)	Rank	Percent Whole Pods	Rank	Oil Content (%)	Rank	Oil Yield (lb/ac)	Rank
High	High	150	8	12.0	12	38.8	12	60	9
	Medium	157	6	12.0	11	41.0	10	64	7
	Low	174	5	15.0	7	41.0	10	73	4
	None	263	1	14.4	9	41.3	9	105	1
Low	High	224	2	17.7	2	42.3	7	93	3
	Medium	218	3	18.1	1	43.5	6	96	2
	Low	176	4	16.8	6	41.7	8	73	4
	None	101	11	13.1	10	45.3	5	46	11
None	High	106	10	14.8	8	49.1	1	52	10
	Medium	85	12	17.0	5	48.4	2	41	12
	Low	128	9	17.1	4	46.9	4	60.75	8
	None	152	7	17.2	3	47.2	3	72	6
Mean		161		15.4		43.9		70	
***P* (Irrigation Rate)**		**0.070**		**0.065**		**<0.001**		**0.168**	
LSD (0.05)- Irrigation Rate		NSD		NSD		1.8		NSD	
CV Irrigation Rate (%)		61.2		29.9		6.5		56.1	
P (N Rate)		**0.918**		**0.611**		**0.447**		**0.927**	
LSD (0.05)-N Rate		NSD		NSD		NSD		NSD	
CV N Rate (%)		50.7		24.0		7.0		50.1	
P (Irrig. Rate X N Rate Interaction)		**0.016**		**0.166**		**0.381**		**0.026**	

Table 5. 2008 Euphorbia nitrogen rate x irrigation rate trial.
Southern Oregon Research & Extension Center, Medford, OR.

Irrigation Rate	Nitrogen Rate	Seed Yield (lb/ac)	Rank	Percent Whole Pods	Rank	Oil Content (%)	Rank	Oil Yield (lb/ac)	Rank
High	High	151	4	6.3	12	43.5	12	68	5
	Medium	137	6	7.1	6	48.0	9	65	6
	Low	126	7	6.4	11	44.9	10	56	7
	None	219	3	7.1	6	49.6	5	108	3
Low	High	284	2	6.4	10	44.9	10	132	2
	Medium	113	8	6.8	8	49.5	6	56	7
	Low	146	5	6.6	9	49.3	7	72	4
	None	344	1	11.0	4	50.4	3	173	1
None	High	68	10	13.1	2	50.8	1	35	9
	Medium	70	9	12.2	3	50.6	2	35	9
	Low	49	12	13.5	1	49.2	8	24	12
	None	58	11	10.7	5	49.9	4	29	11
Mean		147		8.9		48.4		71	
***P* (Irrigation Rate)**		**0.001**		**0.003**		**0.028**		**0.002**	
LSD (0.05)- Irrigation Rate		68		2.8		2.5		35	
CV Irrigation Rate (%)		71.4		49.5		8.0		75.8	
***P* (N rate)**		**0.039**		**0.833**		**0.002**		**0.032**	
LSD (0.05)- N Rate		81		NSD		1.9		40	
CV N Rate (%)		81.7		40.9		5.9		83.2	
***P* (Irrig. Rate X N Rate Interaction)**		**0.238**		**0.263**		**0.039**		**0.238**	

Table 6. 2008 Euphorbia row spacing x variety trial.
Klamath Basin Research & Extension Center, Klamath Falls, OR.

Row Spacing	Cultivar	Seed Yield (lb/ac)	Rank	Percent Whole Pods	Rank	Oil Content (%)	Rank	Oil Yield (lb/ac)	Rank
12 inch	Eu005	279	4	16.6	3	42.4	5	114	4
	Eu006	187	8	15.0	7	43.9	2	82	8
	Eu008	259	6	16.1	5	45.0	1	121	3
24 inch	Eu005	261	5	14.5	8	42.2	7	110	5
	Eu006	162	9	16.5	4	42.4	5	68	9
	Eu008	288	3	19.3	2	39.8	9	107	6
36 inch	Eu005	224	7	15.8	6	43.6	3	98	7
	Eu006	452	1	22.6	1	41.9	8	190	1
	Eu008	397	2	13.6	9	43.1	4	172	2
Mean		279		16.7		42.7		118	
***P* (Row Spacing)**		**0.049**		**0.851**		**0.156**		**0.024**	
LSD (0.05)- Row Spacing		108		NSD		NSD		43.420	
***P* (Cultivar)**		**0.492**		**0.621**		**0.996**		**0.446**	
LSD (0.05)-Cultivar		NSD		NSD		NSD		NSD	
***P* (Row Spacing X Cultivar Interaction)**		**0.103**		**0.321**		**0.348**		**0.109**	
CV (%)		45.9		37.3		6.6		43.7	

Table 7. 2008 Euphorbia row spacing x variety trial.
Southern Oregon Research & Extension Center, Medford, OR.

Row Spacing	Cultivar	Seed Yield (lb/ac)	Rank	Percent Whole Pods	Rank	Oil Content (%)	Rank	Oil Yield (lb/ac)	Rank
12 inch	Eu005	370	9	4.6	8	49.7	1	184	9
	Eu006	558	5	7.8	5	48.7	7	260	5
	Eu008	707	4	5.5	7	48.6	8	334	4
24 inch	Eu005	746	3	3.8	9	49.2	5	366	3
	Eu006	426	8	7.8	4	49.3	3	209	8
	Eu008	477	7	7.9	3	49.3	3	234	7
36 inch	Eu005	1025	1	7.2	6	49.5	2	501	1
	Eu006	786	2	10.6	2	48.6	8	380	2
	Eu008	494	6	11.1	1	48.9	6	241	6
Mean		621		7.4		49.1		301	
***P* (Row Spacing)**		**0.288**		**<0.001**		**0.916**		**0.254**	
LSD (0.05)- Row Spacing		NSD		1.8		NSD		NSD	
***P* (Cultivar)**		**0.591**		**0.001**		**0.691**		**0.519**	
LSD (0.05)- Cultivar		NSD		1.8		NSD		NSD	
***P* (Row Spacing X Cultivar Interaction)**		**0.244**		**0.488**		**0.944**		**0.247**	
CV (%)		62.1		28.4		3.6		60.4	

Table 8. 2008 Euphorbia irrigation rate x seeding date trial.
Klamath Basin Research & Extension Center, Klamath Falls, OR.

Irrigation Rate	Seeding Date	Seed Yield (lb/ac)	Rank	Percent Whole Pods	Rank	Oil Content (%)	Rank	Oil Yield (lb/ac)	Rank
High	May 9	263	1	14.4	5	41.3	6	105	1
	June 2	50	6	17.4	3	46.7	4	24	6
Low	May 9	101	4	13.1	6	45.3	5	46	4
	June 2	154	2	19.0	1	48.6	2	75	2
None	May 9	152	3	17.2	4	47.2	3	72	3
	June 2	91	5	18.0	2	51.4	1	46	4
Mean		135		16.5		46.8		61	
***P* (Irrigation Rate)**		**0.377**		**0.597**		**<0.001**		**0.887**	
LSD (0.05)- Irrigation Rate		NSD		NSD		2.0		NSD	
CV Irrigation Rate (%)		46.0		26.0		4.8		42.0	
***P* (Seeding Date)**		**0.003**		**0.020**		**<0.001**		**0.007**	
LSD (0.05)- Seeding Date		44		2.6		1.5		18	
CV Seeding Date (%)		46.1		22.4		4.5		40.3	
***P* (Irrig. Rate X Seeding Date Interaction)**		**<0.001**		**0.274**		**0.489**		**<0.001**	

Table 9. 2008 Euphorbia irrigation rate x seeding date trial.
Southern Oregon Research & Extension Center, Medford, OR.

Irrigation Rate	Seeding Date	Seed Yield (lb/ac)	Rank	Percent Whole Pods	Rank	Oil Content (%)	Rank	Oil Yield (lb/ac)	Rank
High	May 1	219	3	7.1	6	49.6	4	108	3
	May 27	87	4	12.9	3	50.0	2	44	4
Low	May 1	344	1	11.0	4	50.5	1	170	1
	May 27	250	2	15.7	1	48.4	5	120	2
None	May 1	58	5	10.7	5	49.9	3	29	5
	May 27	32	6	13.7	2	47.9	6	16	6
Mean		165		11.9		49.4		81	
***P* (Irrigation Rate)**		**0.002**		**0.247**		**0.426**		**0.003**	
LSD (0.05)- Irrigation Rate		116		NSD		NSD		59	
CV Irrigation Rate (%)		77		39.4		3.3		79.5	
***P* (Seeding Date)**		**0.022**		**0.038**		**0.009**		**0.019**	
LSD (0.05)- Seeding Date		70		4.2		0.9		34	
CV Seeding Date (%)		60		49.8		2.5		59.7	
***P* (Irrig. Rate X Seeding Date Interaction)**		**0.429**		**0.846**		**0.052**		**0.435**	