Agronomic Requirements of *Euphorbia lagascae:* A Potential New Drought-Tolerant Crop for Semi-Arid Oregon: 2011 Results.

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Background and Rationale

Euphorbia lagascae (Euphorbiaceae- 'spurge family') has been recognized as one of the more promising potential new industrial crops for the drier regions in the temperate zone (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* was unique among the 58 euphorbs tested (and almost unique among all plants) in that the seed oil contained high

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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 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 et al., 1986). 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.

For more details on euphorbia's unique properties, crop status, current competitors, and likely uses in industry please refer to a more detailed discussion, including additional references, in our earlier reports (Roseberg and Shuck, 2008 and 2009).

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 in Medford, OR, we decided to proceed with additional, more detailed agronomic studies over multiple years, beginning in 2008 (Roseberg and Shuck, 2008 and 2009; Roseberg and Bentley, 2010).

The objective of this series of studies was to examine euphorbia's response to crop management practices such as seeding date, irrigation rate, nitrogen fertilization, plant density, seeding rate, and seed type in semi-arid southern Oregon locations. In 2011 these studies were duplicated in both the Rogue Valley and in the Klamath Basin to compare responses in two dramatically different climates (grown at SOREC near Medford, OR and at KBREC near Klamath Falls, OR).

Materials and Methods Summary

Studies were conducted at KBREC (Poe fine sandy loam) and SOREC (Central Point sandy loam). Two experiments were duplicated at both locations: I) Row spacing by seeding rate by irrigation rate; and II) Seed type by irrigation rate. At KBREC these two experiments also had an additional factor of two seeding dates compared to only one seeding date at SOREC. At both locations, three irrigation treatments ('high', 'low', and 'none') were imposed as one of the treatment factors for both experiments. After initial irrigation of all plots to encourage uniform germination (if rainfall was not sufficient), irrigation rates at each location were decided based on the Kimberly-Penman evapotranspiration calculated by the nearest US Bureau of Reclamation Agricultural Meteorological (AgriMet) automated weather station located at both KBREC and SOREC (US Bureau of Reclamation, 2011). Irrigation was applied at rates approximately equal to 50% of calculated evapotranspiration in the 'high' treatment and 25% of evapotranspiration in the 'low' treatment. After emergence, irrigation was not applied to the 'none' treatment. Irrigation was shut off in early August to expedite dry-down and allow harvest by late summer or early fall. In this region, we have observed that if euphorbia is irrigated much later than early August it will tend to remain green and not dry down sufficiently for harvest by fall.

Kincaid Plot Drill

In addition to Experiments I and II, two additional studies were done in 2011 at SOREC only. Our previous studies indicated that euphorbia is tolerant of both pendimethalin and ethalfluralin herbicides applied pre-plant incorporated (PPI) (Roseberg, 1998 and 2000). Earlier observational studies also suggested that seed yield from traditional direct-combining harvest might be improved by a preliminary cutting step (swathing) followed by a drying period of a few days to one or two weeks in the field before combining to allow all plant material and seeds to dry uniformly and thresh more completely (Roseberg et al., 1997), as is sometimes done with other crops such as canola or grass seed.

Thus, to examine the effect of harvest method on crop yield, a strip trial including both harvest methods (Experiment III) was set up in the same field as Experiments I and II in areas treated with both herbicides. To examine the potential effect of the two herbicides on crop growth and yield, a strip trial including both herbicides (Experiment IV) was set up in the same field as the other experiments in areas later harvested using both harvest methods. Experiments III and IV were done only at SOREC. Within their separate, respective treatment areas, Prowl H_2O® (pendimethalin) was applied PPI at 4.21 pint/ac (2.0 lb a.i./ac), and Sonalan® (ethalfluralin) was applied at 5.33 pint/ac (2.0 lb a.i./ac) PPI with a ground sprayer and tractor-mounted rototiller on May 13 at SOREC. At KBREC, the herbicides were applied PPI on April 19 (at the same rates), also with a ground sprayer and tractor-mounted rototiller. At KBREC, pendimethalin was applied only to certain border areas for observational purposes, but harvest data was not collected in those areas. At both locations, only ethalfluralin (at the same rate and method) was applied to the plot areas of Experiments I and II.

For all trials the euphorbia seed was drilled using a tractor mounted modified Kincaid (Kincaid Equipment Mfg.) plot drill. Weed control was very good, but during the growing season the relatively few weeds were controlled by manual cultivation. No fertilizer was applied to any of the trials. The plots strips at SOREC that were swathed prior to combining (Experiments III and IV) were cut with a modified John Deere model 800 draper-type swather with a 12-ft-wide header. All plots were combined with a Hege (Hans-Ulrich Hege) plot combine with a 4.5-ft-wide header. Harvested seed was cleaned using a Clipper seed cleaner.

Hege Plot Combine

Draper Swather

Large Clipper Cleaner & Grain Elevator

During the harvest process, euphorbia seed will separate into one of three forms. The intact capsule (called 'whole pods' or WP) consists of three sections, with each section containing an individual seed. 'Partial pods' (PP) consist of these individual seeds that are still retained in the individual chambers, but the chambers have separated from one another, while 'good seed' (GS) indicates clean individual seeds that have separated completely from all remnants of the original capsules or pods. After cleaning, the percentage of GS, PP, and WP 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 weighted proportion of good seed within the partial pods and whole pods.

All measured parameters were analyzed statistically using SAS® for Windows, Release 9.1 (SAS Institute, Inc.) software, according to each experiment's design. 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. Row Spacing by Seeding Rate by Irrigation Rate Studies

KBREC

This study was set up as a split-split plot design with irrigation rate as the main plot, seeding date as the subplot, and the row spacing/seeding rate treatment as the sub-subplot. The seeding dates were April 27 and May 24. Irrigation applications totaled 9.86 inches applied over 12 dates in the 'high' treatment during the growing season, 4.72 inches applied over 7 dates in the 'low' treatment, and 2.15 inches of irrigation applied over 3 dates in the 'none' treatment, in addition to 2.56 inches of rainfall (including 1.24 inches from May 1 through August 31) (Table 1). The calculated Penman evapotranspiration from May 1 through August 31 (after which plants were drying down) totaled 27.9 inches.

Because it did not seem logical or practical to include all possible combinations of likely row spacing and seeding rates in a factorial design, we chose six different row spacing/seeding rate (RSSR) combinations to be imposed as discrete treatments. The RSSR treatment combinations were as follows: a) 6 inch row spacing seeded at a density of 20 seeds/ft^2; b) 6 inch row spacing at 30 seeds/ft^2; c) 12 inch row spacing at 30 seeds/ft^2; d) 12 inch row spacing at 60 seeds/ft^2; e) 24 inch row spacing at 7.5 seeds/ft^2; f) 24 inch row spacing at 15 seeds/ft^2; g) 24 inch row spacing at 30 seeds/ft^2; and h) 36 inch row spacing at 20 seeds/ft^2. Thus these treatments include some equivalent seeding rates occurring at different row spacings, and also some treatments that are a stepwise increase in seeding rate from other treatments having the same row spacing.

We attempted to begin direct combine operations on October 18, but it was clear the plants were still too green for proper combining. Due to the predicted cooler fall weather, at KBREC we elected to swath nearly all plots on October 19 with a Swift Mfg Co. plot swather (with a 5 ft header) to accelerate plant dry-down. Plants were allowed to dry in the field until October 25, when seed from all plots were harvested using the Hege plot combine.

SOREC

This study was laid out and seeded using the same methods as the KBREC study, but because there was just one seeding date, it was set up as a split-plot design, with irrigation rate as the main plot and the RSSR treatment as the sub-subplot. Plots were seeded on May 20. A total of 7.40 inches of irrigation was applied over 6 applications in the ‘high’ treatment, 3.00 inches of irrigation was applied over 3 applications to the ‘low’ treatment, and no irrigation water was applied to the ‘none’ treatment during the growing season (sufficient rainfall occurred soon after seeding to allow good germination). An additional 4.83 inches of precipitation fell from May through October (including 3.10 inches from May 20 to August 31) (Table 2). Calculated Penman evapotranspiration from May 20 through August 31 was 25.3 inches. Unlike at KBREC, all the plots in this trial dried down sufficiently without the need for swathing and thus were harvested using the Hege plot combine only. The plots in the ‘none’ irrigation treatment were harvested on September 28, and the plots in the ‘high’ and ‘low’ treatments were harvested on October 20.

Results and Discussion

KBREC

Overall, seed yields were higher than in previous year’s experiments. Difference in seed yield due to irrigation treatment were not significant ($P = 0.05$), but there was a general trend for seed yield to increase as irrigation increased from ‘none’ to ‘low’ ($P= 0.079$) (Table 3). The effect of the seeding date factor and RSSR treatments were both significant, but their interaction was not significant. The April 27 seeding date typically yielded higher than the May 24 seeding date, although this pattern was not as clear in the ‘none’ irrigation treatment areas. It is not surprising that the longer growing season for the April 27 seeding date would produce higher yields, but the lack of benefit from early seeding in the 'none' irrigated treatment is different than some past results.

Seed yields were generally highest for the 6 and 12 inch row spacings, although some other treatment combinations also produced fairly high yields. Within each row spacing, increasing the seeding rate did not typically result in an increased seed yield, suggesting that given a reasonable plant density, euphorbia can compensate for greater or lesser plant density by either growing more upright or by branching and producing more seedpods on secondary branches as space allows. Comparing cases having equal seeding density but different row spacing, the seed yield from those seeded at 20 seeds/ft^2 in a 6-inch row spacing were almost always much higher than those also seeded at 20 seeds/ft^2 in a 36-inch row spacing, suggesting that the more uniform areal spacing in the 6 inch rows was beneficial. For treatments seeded at 30 seeds/ft^2, the 24-inch row spacing consistently resulted in lower yield than the 6 or 12 inch rows, again suggesting that more equidistant plant geography was helpful.

Seed oil percentages were generally higher than in many previous experiments; almost all treatment combinations resulted in seed oil percent above 52.0. Differences in seed oil percent were only significant for seeding date and there was a significant irrigation rate by seeding date interaction. The April 27 seeding date usually had higher seed oil percent for 'high' irrigation, but the opposite was true for the 'none' irrigation. Because of the narrow spread in seed oil percent, differences in oil yield followed essentially the same patterns and degrees of significance as the seed yields did.

The percent whole pods measurement is an indication of the maturity and relative indehiscence of the plants at time of harvest. Results were not wildly different across the entire experiment. Even though differences were not significant for irrigation rate or seeding date, differences were significant due to RSSR treatments. The 24-inch rows at 15 and 7.5 seeds/ft^2 generally had the highest percent whole pods, especially where moisture was more limiting (later seeding date and/or less irrigation), suggesting that within limits, plants that were able to branch out tended to produce more pods that matured later and/or resisted threshing better compared to denser plantings.

Plant heights differences were significant for irrigation rate only, and heights generally decreased as irrigation rate decreased, except for the narrower row spacings under the 'none' irrigation treatment on the second seeding date only, which tended to be taller than the same seeding date and RSSR treatments.

Stand count is an indication of how well the seed germinated and ultimately how dense the established stand would become (as a function of seeding rate). Stand counts were taken twice soon after plants germinated and emerged, and differences were only significant for RSSR treatment. Not surprisingly, the 12 inch spacing/60 seeds/ft^2 combination had the highest stand counts in every irrigation rate by seeding date case, as it was the only treatment seeded at the 60 seeds/ft^2 rate. At any given row spacing, increased seeding rate resulted in increased stand count. Comparing cases having equal seeding density but different row spacing, the stand count from those seeded at 20 seeds/ft^2 in a 6-inch row spacing was always much higher than those also seeded at 20 seeds/ft^2 in a 36-inch row spacing, suggesting that the more uniform areal spacing in the 6 inch rows was beneficial. For treatments seeded at 30 seeds/ft^2, the 24-inch row spacing consistently resulted in lower yield than the 6 or 12 inch rows, again suggesting that more equidistant plant geography was helpful. Thus, the pattern in the stand count results essentially parallel those observed for the seed yield results (discussed above). In most cases, stand counts dropped slightly from the first observation to the second, indicating some die-off after initial germination, probably due to normal plant competition.

Germinating Euphorbia Seedlings

SOREC

Seed yields were generally lower than in a previous row spacing trial conducted at SOREC. In previous trials at SOREC, seeding as early as March resulted in higher seed yields than those observed in 2011, when seeding was delayed until May 20.

Differences due to irrigation rate were significant for seed yield, seed oil percent, and oil yield (Table 4). Seed yields and oil yield both significantly increased at each level of increased irrigation. Due to the relatively late seeding date (May 20), plants in this trial were under more moisture stress for the entire season than euphorbia seeded earlier would have been (as has sometimes been possible in the past). Seed oil content increased as irrigation decreased, sometimes significantly. Seed oil percentages tended to be higher in the 6 inch and 12 inch row spacings, but differences were subtle. Despite this, oil yields followed the same patterns as the seed yields. Differences in seed yield, seed oil percent, and oil yield were also significantly different due to RSSR treatment. At the 20 seeds/ft^2 seeding rate, narrow row spacing (6 inch vs 36 inch) increased yield, but not for the 'none' irrigation treatment, suggesting that plants in narrow rows can benefit from additional moisture, but narrow rows are not necessarily helpful where moisture is limiting. For given each row spacing, increasing the seeding rate tended to increase seed yield only for the 'high' irrigation treatment, suggesting that when moisture is more limiting euphorbia compensates for a lower seeding rate by producing more seed pods on more side branches. The one consistent exception to this yield pattern was for the lowest seeding rate 7.5 seeds/ft^2 (in a 24-inch row) which had the lowest yield in every case, suggesting that this seeding rate was too low for euphorbia to compensate by increasing the number of seedpod-bearing side branches. This pattern was not observed at KBREC.

Differences in percent whole pods were not significant due to irrigation, but differences were significant for RSSR treatment. The percent whole pods tended to be higher where plant populations were lower (wider row spacings and/or lower seeding rates), similar to results observed at KBREC, suggesting that within limits, plants that were able to branch out more tended to produce more pods that matured later and/or resisted threshing better compared to denser plantings.

Differences in plant height due to irrigation were significant, but were not different due to RSSR treatment, similar to the results at KBREC. Plant height decreased dramatically as irrigation rates decreased. As was observed at KBREC, stand counts were highest for the 12 inch spacing, 60 seeds/ft^2 entry, and at any given row spacing, increased seeding rate resulted in increased stand count. Comparing cases having equal seeding density but different row spacing, the stand count from those seeded at 20 seeds/ft^2 in a 6-inch row spacing was always higher than those also seeded at 20 seeds/ft^2 in a 36-inch row spacing, suggesting that the more uniform areal spacing in the 6 inch rows was beneficial. For treatments seeded at 30 seeds/ft^2, the 24-inch row spacing consistently resulted in lower yield than the 6 or 12 inch rows, again suggesting that more equidistant plant geography was helpful. In many cases the pattern in the stand count results paralleled those observed for the seed yield results (discussed above). In most cases, there was not much difference in stand count between the first and second observations, suggesting less seedling loss due to competition than was observed at KBREC. The generally lower overall stand counts seem to confirm that stand count was more limiting in general at SOREC, partially explaining the lower overall yields there.

II. Seed Type by Irrigation Rate Studies

Good Seed, Partial Pods, and Whole Pods

KBREC

This study was set up as a split-split plot design with irrigation rate as the main plot, seeding date as the subplot, and the seed type as the sub-subplot. The seeding dates, irrigation rates, precipitation, and calculated evapotranspiration were the same as in Experiment I at KBREC described above (Table 1). Plots were swathed on October 19 and combined on October 25 using the same equipment and methods as in Experiment I

Euphorbia seed is produced in capsules (also called seed pods) that normally contain three seeds each (Vogel et al., 1993; Verdolini et al., 2004). Each individual seed is contained within a separate, small chamber or section. Thus, the intact capsule (called 'whole pods' or WP) consist of three sections, with each section containing an individual seed. During the harvest process, euphorbia seed will thresh out into one of three forms: 'whole pods', 'partial pods' or PP (seed still retained in the individual chambers that have separated from one another), and 'good seed' or GS (clean individual seeds that have separated completely from all remnants of the original capsules or pods). Once seeds separate into these three forms during harvest and cleaning, it would be difficult to further separate seed from their pods because euphorbia seed is very soft (due to the high oil content) and easily damaged. As was described in our report of 2010 studies, it would be useful to know if PP or WP could be seeded directly, and whether they suffer any loss of germination vigor, crop growth, or ultimate yield compared to using GS.

The three different seed types (GS, PP, and WP) were seeded on April 27 and May 24. All plots were seeded at a rate of 30 actual seeds/ft^2, which turned out to be a rate of 28.8 lb/ac for GS, 59.9 lb/ac for PP, and 66.3 lb/ac for WP. All rows were spaced at 24 inch.

SOREC

This study was laid out and seeded using the same methods as the KBREC study, but because there was just one seeding date, it was set up as a split-plot design, with irrigation rate as the main plot and the seed type as the sub-subplot. The seeding date, irrigation rates, precipitation, and calculated evapotranspiration were the same as in Experiment I at SOREC described above (Table 2). Unlike at KBREC, all the plots in this trial dried down sufficiently without the need for swathing and thus were harvested using the Hege plot combine only. The plots in the 'none' irrigation treatment were harvested on September 28, and the plots in the 'medium' and 'wet' irrigation treatments were harvested on October 20.

Results and Discussion

KBREC

Overall, seed yields were higher than in some previous years. Differences in seed yield and oil yield due to irrigation rate were not quite significant at P=0.05 (Table 5), although yield seemed to be slightly depressed where no irrigation was applied. Seeding date and seed type both a significant effect on seed yield and oil yield. Seed yield was highest for the April 27 seeding date under both 'high' and 'low' irrigation, but yield tended to be higher from the May 24 seeding date in the 'none' irrigation treatment. In almost every treatment combination, using GS resulted in higher yields, whereas PP and WP often had lower, yet similar, seed yields.

Differences in seed oil percent were significant for irrigation treatment, but not for seeding date or seed type. Seed oil percent was highest at the two extremes; either under 'high' irrigation from the earlier seeding date or under no irrigation from the later seeding date. Despite these differences in seed oil percent, the oil yield essentially followed the same pattern as seed yield.

Differences in percent whole pods were not significant due to seeding date, but differences were significant for irrigation rate and seed type. Percent whole pods generally decreased as irrigation rate decreased. Seeding with WP tended to produce a higher percent of whole pods at harvest, while seeding with GS and PP resulted in nearly equal percent whole pods at harvest. Differences in plant heights were significant for irrigation rate, seeding date, and seed type, yet none of the interactions were significant. Plant heights steadily decreased as irrigation rate decreased. Euphorbia was the almost always tallest from the later (May 24) seeding date. Using GS tended to result in taller plants, but height differences were smaller in this trial than in some previous trials.

Differences in stand counts were not significant due to irrigation treatment, but were significant for seeding date and seed type. The April 27 seeding date often had higher stand counts than the May 24 seeding date, but this was not true under no irrigation. In some cases using GS resulted in the highest stand counts, and in other cases using PP resulted in higher stand counts. Seeding with WP always resulted in the lowest stand count. However, because seeding with WP did not always result in the lowest seed yield, the euphorbia plant must have compensated in some low-density situations by producing more seedpod –bearing branches when plant populations were less dense.

SOREC

As in Experiment I at SOREC, seed yields for Experiment II were not high. Observed differences in seed yield and oil yield were statistically significant for both irrigation rate and seed type (P = 0.05) (Table 6). Seed yield and oil yield increased with each increment of increased irrigation. Yields were generally highest where GS was seeded, but differences between GS and PP were not always significant. Seeding with WP resulted in the lowest yield in each case, though again differences between WP and PP were not always significant. Differences in seed oil percent were not statistically different for either irrigation rate or seed type; however, seed oil percent tended to increase as irrigation decreased. Because of the small differences in seed oil percent, oil yields followed the same patterns as seed yields.

Differences in percent whole pods were significant for both irrigation rate and seed type. The 'low' irrigation treatment produced the highest percent whole pods, and seeding with WP tended to result in the highest percent whole pods at harvest, although in both cases the observed differences were fairly small.

Differences in plant height were significant due to irrigation rate, but not due to seed type. Plants height increased significantly with each increment of increased irrigation. Stand counts were not significantly different due to irrigation rate for the first observation (P=0.087), but differences were significant by the second observation date. For both dates, however, stand counts followed the same pattern. Irrigation rate had little effect on stand count for WP, but had a larger effect for PP, which had higher stand counts under the ‘low’ irrigation treatment. Seeding with WP resulted in lower stand counts in each case, although (as in the trial at KBREC) stand count did not automatically correlate with ultimate seed yield, again showing euphorbia’s ability to compensate somewhat for lower population. Stand counts tended to be highest in the ‘medium’ irrigation treatment, while stand counts in the ‘high’ irrigation treatment were similar to those in the ‘none’ irrigation treatment. Stand counts tended to be highest for the ‘partial pods’ in the ‘low’ and ‘none irrigation treatments. In nearly every case, stand counts dropped slightly between the first and second observations, although none of these stand count values were large compared to the other 2011 trials.

III. Harvest Method by Irrigation Rate

As noted above, portions of both locations were treated with either Sonalan® or Prowl® herbicides PPI. Within each of these areas, a harvest method by irrigation rate evaluation was set up. Due to harvesting equipment limitations, these comparisons were only possible at SOREC. Due to the need to apply irrigation and perform harvest operations in strips, randomization of the harvest method by irrigation treatment combinations was restricted within each replication. Thus, the harvest method by irrigation rate trial was set up as a split-block design, with irrigation rate and harvest method as the two main blocks. This design results in fewer degrees of freedom for the error term for each main block treatment, and thus less sensitive comparisons with the F test.

Plots were seeded on May 20 using ‘partial pods’ from crops grown in 2009 and 2010 with the Kincaid (Kincaid Equipment Mfg.) three row plot drill, at 30 seeds/ft^2 with 24-inch row spacing. Irrigation amounts, number of applications, and precipitation were the same as in the other SOREC trials as described above (Table 2). Within each irrigation treatment zone, there were two harvest methods: ‘swathed’ or ‘direct combined’. The ‘swathed’ plots were first cut with a modified John Deere model 800 draper-type swather on October 7, allowed to dry in the field, and then combined with the Hege plot combine on October 20. The ‘direct combined’ plots were harvested with the Hege plot combine only, on September 28 in the ‘none’ irrigation treatment, and on October 20 in the ‘high’ and ‘low’ irrigation treatments.

Results and Discussion

Sonalan®-Treated Areas

Differences between irrigation treatments were significant (P=0.05) for all measured factors except seed oil content, and differences between harvest method treatments were significant for all measured factors except percent whole pods (Table 7). Seed yield and oil yield increased with each increment of increased irrigation. The ‘direct combined’ plots yielded higher than the ‘swathed’ plots (this difference was significant for two of the three irrigation treatments). Differences in seed oil percent were significantly different for harvest method only. The ‘direct combine’ treatment had higher seed oil percent for all irrigation treatments, suggesting that seed was slightly more mature (and thus had slightly higher oil percent) at time of direct combining rather than at time of swathing, when seed was slightly less mature. Despite these differences in seed oil percent, oil yields followed the same pattern as seed yields.

The 'high' irrigation rate had the lowest percent whole pods, and although the results were not statistically significant, the 'direct combine' plots tended to have lower percent whole pod numbers. Plant heights increased as irrigation rate increased. Although differences in plant height due to harvest method were significant, such a connection does not make sense physiologically. In fact, these differences did not follow a pattern, as shown by the significant irrigation by harvest method interaction. Stand counts were highest in the 'low' irrigation treatment and the 'direct combine' plots had higher stand counts. Again, the relationship between stand counts (taken during seedling growth stage) and harvest method does not seem logical. In nearly every case, stand counts dropped between the first and second observations, which seems to be normal for euphorbia as plants grow larger and begin to compete with each other and any weeds present.

Prowl®-Treated Areas

Where Prowl® was used in the 'high' irrigation areas, weeds became a large problem as the season progressed. Due to insufficient hand-weeding later in the season in plots destined for the 'swathing' harvest treatment, weeds became excessive and these plots could not be harvested properly, thus no harvest data or statistical comparisons could be made for this treatment combination.

Overall, the pattern of results in the Prowl®-treated areas were similar to those in the Sonalan® - treated areas, although the statistical comparisons differed somewhat (Tables 7 and 8). Differences between irrigation treatments were significant (P=0.05) only for seed yield, oil yield, and height (Table 8). Differences between harvest method treatments were significant only for percent whole pods, but were barely above the P=0.05 threshold for plant height and stand count.

Seed yields usually increased significantly as irrigation rate increased (Table 8). Although the differences were not statistically significant, the 'direct combined' plots tended to have higher seed yields than the 'swathed' plots. Oil yields followed this same pattern. Differences in percent whole pods were statistically significant for harvest method only, followed a similar pattern to that observed in the Sonalan®-treated areas. Plants height generally increased as irrigation rate increased. Differences in stand counts were not significant for either irrigation or harvest method, but stand counts tended to be higher in the 'low' irrigation treatment, similar to the pattern observed in the Sonalan®-treated areas.

IV. Herbicide Treatment by Irrigation Rate

Although the two different herbicides were applied to different areas at both locations, data was only collected from herbicide-treated plots in a way that allowed statistical comparison at SOREC. As noted above, Prowl H_2O® (pendimethalin) was applied PPI at 4.21 pint/ac (2.0 lb a.i./ac), and Sonalan® (ethalfluralin) was applied at 5.33 pint/ac (2.0 lb a.i./ac) PPI with a ground sprayer and tractor-mounted rototiller on May 13 at SOREC (within their respective treatment areas).

Due to the need to apply irrigation and herbicides in strips, randomization of the herbicide by irrigation treatment combinations was restricted within each replication. Thus, the herbicide by irrigation rate trial was set up as a split-block design, with irrigation rate and herbicide treatment as the two main blocks. This design results in fewer degrees of freedom for the error term for each main block treatment, and thus less sensitive comparisons with the F test. Plots were seeded on May 20 with the Kincaid (Kincaid Equipment Mfg.) three row plot drill, at 30 seeds/foot^2 with a 24inch row spacing (same equipment and procedures as Experiment III), using 'Partial pods' grown in 2010. Irrigation applications and precipitation were the same as in the other SOREC trials as described above (Table 2).

The herbicide treatment plots were later harvested using two harvest methods: 'swathed' or 'direct combined', using essentially the same equipment and procedures used in Experiment III above. Thus, the 'swathed' plots were first cut with the modified John Deere model 800 draper-type swather on October 7, and then combined with the Hege plot combine on October 20. The 'direct combined' plots were harvested with the Hege plot combine only, on September 28 in the 'none' irrigation treatment, and on October 20 in the 'high' and 'low' irrigation treatments.

Results and Discussion

Swathed Areas

Differences between herbicide treatments were not significant for any of the measured parameters (Table 9). Differences between irrigation rates were significant for all parameters measured except plant height. Seed yields tended to increase as irrigation rate increased. On the other hand, seed oil percent increased as irrigation rate decreased. Despite this effect on seed oil percent, oil yields followed the same pattern as seed yields. As was seen in other 2011 studies, percent whole pods decreased as irrigation rate increased. Stand counts were low for all treatment combinations compared to other 2011 trials, but were generally highest for the 'low' irrigation rate, especially on the second observation date.

Direct Combined Areas

Yields were generally higher in the 'direct combine' areas than in the 'swathed' areas (comparing Tables 9 and 10). Differences due to irrigation rate were significant only for seed yield, oil yield, percent whole pods, and height (Table 10). Seed yield and oil yield followed the same trend as in most other trials; yields decreased as irrigation rate decreased. Percent whole pods were highest in the 'low' irrigation treatment. As was often seen in other trials, plant heights decreased as irrigation rate decreased.

Differences due to herbicide treatments were not significantly different for any of the measured parameters except percent whole pods (Table 10). Although the percent whole pods was low in every case, the plots treated with Sonalan® had a significantly higher percent whole pods than those treated with Prowl®.

The focus of this study was more about euphorbia's tolerance of the herbicides and not directly about herbicide efficacy on weeds. Thus, we did not take detailed data regarding weed population, so statistical comparisons cannot be made about weed vigor or competition *per se*. As the season progressed we controlled weeds fairly well with hand cultivation. Casual observation of the plots indicated that weed control was much better in the areas treated with Sonalan® compared to those treated with Prowl®, and measurements of euphorbia's growth and yield may have been different if we had not undertaken hand weeding. It was also observed that euphorbia treated with Sonalan® seemed to grow more slowly during the early part of the season; however, the stand count, plant height, and yield data suggest that euphorbia was able to recover from any initial stunting and produce normal plants with equivalent yield.

Conclusions

Euphorbia is very flexible, and can adapt to many different growing conditions. It produces a very unusual oil and can grow with limited inputs under harsh conditions, and could be a useful crop in the western US and in similar environments elsewhere. The series of experiments we have conducted at SOREC and KBREC over the years confirm that euphorbia is able to survive and produce a harvestable seed yield with limited inputs, even under completely non-irrigated conditions, but that seed yield is enhanced by some irrigation and some level of crop management.

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

Seed yields tended to be highest at the narrower 6 inch and 12 inch row spacings. Seeds also tended to mature sooner in these row spacings. Our "typical" seeding rate of 30 seeds/ft^2 did well in most cases, and at either the 20 or 30 seeds/ft^2 seeding rate, using narrower rows (which resulted in a more uniformly dispersed plant stand) tended to produce higher yields than the same number of seeds per unit area seeded in wider-spaced rows. Seeding at 7.5 seeds/ft^2 seemed to be too low a rate, but otherwise euphorbia was able to adapt to variations in stand density by producing more pod-bearing side branches when plants were more widely spaced. It might be worthwhile to repeat this study under different conditions to better understand the row spacing/seeding rate interaction.

Neither of the two herbicides seemed to harm euphorbia yields (although we did not have a true non-treated control area in 2011, yields in all four experiments were higher than yields in most previous years). Any initial stunting where euphorbia was treated with Sonalan® appeared to be a short-term effect. The herbicides greatly reduced weed pressure (especially when treated with Sonalan®) and a considerable amount of labor and money was saved by not having to hand weed the trials as we sometimes have in the past.

Direct combined areas generally yielded higher and had higher seed oil percentages than swathed areas. It would be interesting to repeat the harvest method trial to be better understand this effect. In some cases, swathing could be very beneficial because it could allow for the crop to be harvested sooner in the season (avoiding wet fall weather), and allowing it to dry down sooner and more uniformly for combining.

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Table 1. 2011 Precipitation & irrigation for euphorbia experiments.
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
April 10-30	1.30	0.00	0	0.00	0	0.00	0
May	0.81	2.15	3	2.15	3	2.15	3
June	0.14	2.85	3	0.57	1	0.00	0
July	0.29	4.00	5	1.14	2	0.00	0
August	0.00	0.86	1	0.86	1	0.00	0
September	0.02	0.00	0	0.00	0	0.00	0
October	0.53	0.00	0	0.00	0	0.00	0
Total	**2.56**	**9.86**	**12**	**4.72**	**7**	**2.15**	**3**

Table 2. 2011 Precipitation & irrigation for euphorbia experiments.
Southern Oregon Research & Extension Center, Central Point, OR.

		"High" Block		"Low" Block		"None" Block	
Month	Precipitation (inch)	Irrigation (inch)	Irrigation Applications	Irrigation (inch)	Irrigation Applications	Irrigation (inch)	Irrigation Applications
May	2.77	0.00	0	0.00	0	0.00	0
June	1.00	2.60	2	1.00	1	0.00	0
July	0.38	3.60	3	0.80	1	0.00	0
August	0.00	1.20	1	1.20	1	0.00	0
September	0.02	0.00	0	0.00	0	0.00	0
October	0.66	0.00	0	0.00	0	0.00	0
Total	**4.83**	**7.40**	**6**	**3.00**	**3**	**0.00**	**0**

Table 3. 2011 Euphorbia response to irrigation rate, seeding date, & seeding rate/row spacing combinations. Klamath Basin Research & Extension Center, Klamath Falls, OR.

Irrigation Rate	Seeding Date	Row Space & Seed Rate Combo (RSSR)	Seed Yield (lb/ac)	Oil Content %	Oil Yield (lb/ac)	Percent Whole Pods	Plant Height (inch)	Final Stand (per ft^2) 1st Observation	Final Stand (per ft^2) 2nd Observation
High	April 27	6 in 20	1589	53.8	854	2.9	32.3	9.5	11.2
		6 in 30	1208	53.8	652	2.0	28.0	10.9	11.8
		12 in 30	1766	53.2	939	2.8	35.3	11.2	12.3
		12 in 60	1797	53.5	962	3.5	30.8	17.0	19.2
		24 in 7	1003	54.0	544	2.8	30.3	2.1	2.6
		24 in 15	1069	54.0	578	2.7	30.8	2.9	2.8
		24 in 30	1094	54.2	595	3.2	30.5	6.6	6.6
		36 in 20	789	53.6	423	1.8	28.3	2.7	3.0
	May 24	6 in 20	978	52.8	520	1.7	31.8	8.0	10.0
		6 in 30	899	52.8	475	2.2	32.0	15.5	12.4
		12 in 30	1206	52.2	627	2.8	31.3	12.8	12.4
		12 in 60	981	52.5	517	1.7	31.5	22.7	21.2
		24 in 7	632	52.2	330	2.7	29.8	1.7	2.4
		24 in 15	691	51.8	360	3.5	30.0	4.8	5.0
		24 in 30	746	52.5	392	2.7	31.5	7.8	6.8
		36 in 20	998	52.6	526	3.4	32.3	3.7	3.7
Low	April 27	6 in 20	1121	53.2	596	2.4	25.5	9.3	8.4
		6 in 30	1297	52.9	687	2.5	29.0	10.7	13.0
		12 in 30	1198	52.8	632	1.9	28.3	12.3	10.7
		12 in 60	1261	53.0	668	1.8	28.8	24.3	22.9
		24 in 7	723	52.9	382	3.1	26.5	2.2	1.5
		24 in 15	995	52.5	522	2.7	26.8	4.4	3.3
		24 in 30	826	52.2	432	3.0	26.3	7.5	6.7
		36 in 20	891	52.9	473	2.4	26.3	3.6	3.3
	May 24	6 in 20	1085	52.4	568	3.1	28.3	8.5	7.8
		6 in 30	1035	52.3	543	1.8	25.5	12.7	9.3
		12 in 30	1050	53.1	559	2.3	26.0	13.8	13.7
		12 in 60	980	52.5	514	1.9	25.0	19.8	18.6
		24 in 7	865	52.7	457	3.4	27.3	2.3	2.1
		24 in 15	1037	52.3	543	4.4	28.3	4.1	2.6
		24 in 30	896	52.1	469	2.5	29.0	7.7	7.6
		36 in 20	640	52.6	337	2.8	28.0	4.4	5.3
None	April 27	6 in 20	858	52.7	453	2.2	24.8	7.4	6.0
		6 in 30	1037	52.4	543	1.8	25.5	13.7	13.7
		12 in 30	954	53.2	509	2.2	26.8	11.3	10.0
		12 in 60	784	52.1	415	3.0	25.5	17.8	17.6
		24 in 7	540	51.9	282	2.1	24.3	2.4	2.2
		24 in 15	642	53.0	341	2.2	23.5	4.1	4.4
		24 in 30	537	51.3	280	2.0	25.5	6.5	5.6
		36 in 20	436	52.8	231	1.8	27.5	4.5	4.9
	May 24	6 in 20	1116	53.9	602	2.3	28.0	9.2	9.2
		6 in 30	990	53.2	528	2.2	27.8	11.5	13.7
		12 in 30	884	53.1	471	2.3	28.0	9.8	8.0
		12 in 60	900	52.8	476	1.5	27.0	16.0	17.1
		24 in 7	919	53.2	488	4.2	26.3	2.0	2.4
		24 in 15	763	52.8	403	2.4	27.5	5.1	5.1
		24 in 30	545	53.1	291	1.7	24.5	7.2	8.7
		36 in 20	743	53.0	394	2.4	26.8	4.8	5.6
Mean			958	52.8	508	2.5	28.1	8.8	8.6
P **(Irrigation Rate)**			**0.079**	**0.224**	**0.075**	**0.196**	**0.011**	**0.507**	**0.731**
LSD (0.05)- Irrigation Rate			NSD	NSD	NSD	NSD	2.7	NSD	NSD
CV Irrigation Rate (%)			63.9	2.6	63.8	48.5	22.1	46.9	47.0
P **(Seeding Date)**			**0.010**	**0.028**	**0.008**	**0.565**	**0.246**	**0.361**	**0.583**
LSD (0.05)- Seeding Date			82	0.3	44	NSD	NSD	NSD	NSD
CV Seeding Date (%)			26.3	1.6	26.6	59.8	13.6	37.7	41.6
P **(RSSR Rate)**			**<0.001**	**0.684**	**<0.001**	**0.006**	**0.744**	**<0.001**	**<0.001**
LSD (0.05)- RSSR			233	NSD	125	0.6	NSD	2.2	2.3
CV RSSR (%)			42.5	1.9	43.0	39.0	12.2	43.5	46.5
P **(Irrig. Rate X Seeding Date Interaction)**			**<0.001**	**<0.001**	**<0.001**	**0.713**	**0.526**	**0.205**	**0.695**
P **(Irrig. Rate X RSSR Interaction)**			**0.845**	**0.785**	**0.882**	**0.358**	**0.969**	**0.829**	**0.595**
P **(Seeding Date X RSSR Interaction)**			**0.629**	**0.928**	**0.639**	**0.005**	**0.644**	**0.993**	**0.956**
P **(Irrig. Rate X Seeding Date X RSSR Interaction)**			**0.930**	**0.779**	**0.928**	**0.178**	**0.355**	**0.736**	**0.911**

Table 4. 2011 Euphorbia response to irrigation rate, & seeding rate/row spacing combinations. Southern Oregon Research & Extension Center, Central Point, OR.

Irrigation Rate	Row Space & Seed Rate Combo (RSSR)	Seed Yield (lb/ac)	Oil Content %	Oil Yield (lb/ac)	Percent Whole Pods	Plant Height (inch)	Final Stand (per ft^2) 1st Observation	Final Stand (per ft^2) 2nd Observation
High	6 in 20	551	52.5	289	2.8	37.0	7.7	7.5
	6 in 30	557	52.1	290	2.6	39.0	8.5	8.2
	12 in 30	463	52.4	243	1.9	38.5	7.3	6.1
	12 in 60	472	52.1	245	2.2	38.5	11.9	9.4
	24 in 7	317	52.0	165	4.4	36.3	1.7	1.3
	24 in 15	395	51.9	205	4.9	36.3	2.7	2.5
	24 in 30	410	52.6	216	3.0	36.8	4.2	4.3
	36 in 20	411	52.0	213	3.3	38.0	2.2	2.5
Low	6 in 20	452	52.9	239	4.1	29.0	7.2	6.7
	6 in 30	417	53.0	221	3.6	27.3	8.5	8.2
	12 in 30	437	53.1	232	4.3	28.5	6.3	5.8
	12 in 60	356	53.4	190	4.0	26.8	12.1	10.2
	24 in 7	138	52.7	73	6.3	29.8	1.8	3.3
	24 in 15	349	53.1	185	4.0	30.8	3.0	3.1
	24 in 30	339	52.1	176	4.8	30.8	4.3	3.5
	36 in 20	304	52.6	160	4.6	29.0	4.0	2.7
None	6 in 20	98	53.8	53	2.5	19.5	6.0	4.0
	6 in 30	197	54.0	106	1.7	19.3	6.3	8.8
	12 in 30	189	54.3	102	2.2	21.5	5.3	5.9
	12 in 60	148	54.3	80	2.3	21.0	8.7	11.4
	24 in 7	71	52.7	38	4.5	20.3	1.5	1.4
	24 in 15	97	52.9	51	3.2	20.5	2.1	3.4
	24 in 30	98	52.9	52	3.1	20.8	3.3	3.6
	36 in 20	86	53.5	46	4.2	21.0	2.7	3.1
Mean		306	52.9	161	3.5	29.0	5.4	5.3
***P* (Irrigation Rate)**		**<0.001**	**0.002**	**<0.001**	**0.064**	**<0.001**	**0.058**	**0.781**
LSD (0.05)- Irrigation Rate		25	0.5	14	NSD	1.3	NSD	NSD
CV Irrigation Rate (%)		13.4	1.6	14.3	62.6	7.5	37.6	28.0
***P* (RSSR)**		**<0.001**	**0.033**	**<0.001**	**0.001**	**0.838**	**<0.001**	**<0.001**
LSD (0.05)- RSSR Rate		69	0.6	37	2.1	NSD	2.1	1.6
CV RSSR (%)		26.6	1.2	26.8	33.4	7.1	46.7	36.6
***P* (Irrig. Rate X RSSR Interaction)**		**0.040**	**0.035**	**0.044**	**0.904**	**0.475**	**0.842**	**0.612**

Table 5. 2011 Euphorbia response to irrigation rate, seeding date, & seed type.
Klamath Basin Research & Extension Center, Klamath Falls, OR.

Irrigation Rate	Seeding Date	Seed Type	Seed Yield (lb/ac)	Oil Content %	Oil Yield (lb/ac)	Percent Whole Pods	Plant Height (inch)	Final Stand (per ft^2) 1st Observation	Final Stand (per ft^2) 2nd Observation
High	April 27	Good Seed	1058	54.0	571	2.7	29.0	6.4	6.0
		Partial Pod	985	53.8	527	3.2	28.2	6.9	8.6
		Whole Pod	881	53.6	470	4.6	27.0	4.1	3.9
	May 24	Good Seed	939	52.2	490	2.8	32.8	4.6	4.4
		Partial Pod	758	51.7	393	2.5	30.0	3.2	5.7
		Whole Pod	596	52.5	313	3.7	29.3	1.8	2.8
Low	April 27	Good Seed	1052	52.5	552	2.3	27.5	8.4	6.0
		Partial Pod	1124	52.7	592	2.5	26.3	9.9	11.0
		Whole Pod	1337	53.1	713	3.8	26.7	3.6	4.4
	May 24	Good Seed	1005	52.5	526	2.6	29.5	6.7	6.1
		Partial Pod	590	52.0	307	2.3	27.8	2.3	3.1
		Whole Pod	584	52.1	306	2.7	27.3	1.3	1.9
None	April 27	Good Seed	834	52.5	437	1.9	25.8	6.0	6.4
		Partial Pod	622	52.0	324	1.6	24.7	5.1	6.1
		Whole Pod	568	52.6	298	1.5	25.3	3.4	3.3
	May 24	Good Seed	866	54.4	469	2.2	26.7	8.3	6.3
		Partial Pod	713	54.6	387	2.3	29.2	6.7	6.8
		Whole Pod	841	54.5	459	2.9	24.7	2.6	4.6
Mean			853	53.0	452	2.7	27.7	5.1	5.4
***P* (Irrigation Rate)**			**0.057**	**0.015**	**0.073**	**0.028**	**0.014**	**0.236**	**0.842**
LSD (0.05)- Irrigation Rate			NSD	0.6	NSD	0.8	2.0	NSD	NSD
CV Irrigation Rate (%)			37.6	2.1	37.5	58.6	14.0	44.9	45.4
***P* (Seeding Date)**			**0.021**	**0.893**	**0.021**	**0.874**	**0.025**	**0.003**	**0.005**
LSD (0.05)- Seeding Date			144	NSD	76	NSD	1.6	1.1	1.0
CV Seeding Date (%)			41.3	2.0	41.2	35.7	14.1	53.2	45.1
***P* (Seed Type)**			**0.027**	**0.213**	**0.030**	**0.005**	**0.032**	**<0.001**	**<0.001**
LSD (0.05)- Seed Type			132	NSD	71	0.5	1.4	0.9	1.2
CV Seed Type (%)			32.9	1.4	33.3	42.7	10.4	35.7	45.8
***P* (Irrig. Rate X Seeding Date Interaction)**			**0.012**	**<0.001**	**0.007**	**0.023**	**0.757**	**0.004**	**0.011**
***P* (Irrig. Rate X Seed Type Interaction)**			**0.637**	**0.977**	**0.616**	**0.343**	**0.536**	**0.177**	**0.704**
***P* (Seeding Date X Seed Type Interaction)**			**0.240**	**0.985**	**0.257**	**0.700**	**0.370**	**0.006**	**0.031**
***P* (Irrig. Rate X Seeding Date X Seed Type Interaction)**			**0.082**	**0.116**	**0.078**	**0.343**	**0.390**	**0.009**	**0.043**

Table 6. 2011 Euphorbia response to irrigation rate and seed type.
Southern Oregon Research & Extension Center, Central Point, OR.

Irrigation Rate	Seed Type	Seed Yield (lb/ac)	Oil Content %	Oil Yield (lb/ac)	Percent Whole Pods	Plant height (inch)	Final Stand (per ft^2) 1st Observation	Final Stand (per ft^2) 2nd Observation
High	Good Seed	424	51.4	217	3.1	35.5	4.5	3.5
	Partial Pod	377	52.2	197	3.3	36.7	3.8	3.3
	Whole Pod	355	52.1	185	4.6	34.8	2.1	1.9
Low	Good Seed	271	52.5	142	5.2	27.5	4.6	5.0
	Partial Pod	314	53.0	166	4.9	27.5	7.9	5.8
	Whole Pod	199	52.3	104	7.5	28.5	2.7	1.9
None	Good Seed	159	53.2	85	4.2	21.3	4.2	3.4
	Partial Pod	129	53.0	68	3.8	20.8	4.3	4.3
	Whole Pod	84	53.0	40	3.8	19.8	2.1	1.8
Mean		257	52.5	134	4.5	28.1	4.0	3.4
***P* (Irrigation Rate)**		**<0.001**	**0.079**	**<0.001**	**0.007**	**<0.001**	**0.087**	**0.008**
LSD (0.05)-Irrigation Rate		50	NSD	26	1.3	2.1	NSD	0.8
CV Irrigation Rate (%)		26.3	2.5	26.4	39.7	10.0	53.6	30.6
***P* (Seed Type)**		**0.048**	**0.808**	**0.042**	**0.010**	**0.672**	**0.002**	**<0.001**
LSD (0.05)- Seed Type		60	NSD	31	0.8	NSD	1.4	0.6
CV Seed Type (%)		31.5	3.0	31.6	23.5	7.3	47.5	23.4
***P* (Irrig. Rate X Seed Type Interaction)**		**0.549**	**0.805**	**0.510**	**0.052**	**0.471**	**0.127**	**0.204**

Table 7. 2011 Euphorbia response to harvest method in Sonalan-treated area. Southern Oregon Research & Extension Center, Central Point, OR.

Irrigation Rate	Harvest Method	Seed Yield (lb/ac)	Oil Content %	Oil Yield (lb/ac)	Percent Whole Pods	Plant Height (inch)	Final Stand (per ft^2) 1st Observation	Final Stand (per ft^2) 2nd Observation
High	Swathed	266	51.3	137	4.0	25.5	1.3	0.8
	Direct Combine	377	52.2	197	3.3	36.7	3.8	3.3
Low	Swathed	184	51.4	95	5.4	25.5	2.4	2.0
	Direct Combine	314	53.0	166	4.9	27.5	7.9	5.8
None	Swathed	105	52.0	55	5.7	23.4	1.3	1.3
	Direct Combine	129	53.0	68	3.8	20.8	4.3	4.3
Mean		218	52.0	113	4.6	26.1	3.0	2.5
***P* (Irrigation Rate)**		**<0.001**	**0.066**	**<0.001**	**0.004**	**<0.001**	**<0.001**	**<0.001**
LSD (0.05)-Irrigation Rate		21	NSD	11	0.7	2.1	1.2	0.6
CV Irrigation Rate (%)		15.6	1.6	13.2	19.2	15.2	51.2	32.9
***P* (Harvest Method)**		**0.024**	**0.033**	**0.021**	**0.131**	**0.023**	**0.002**	**<0.001**
LSD (0.05)- Harvest Method		63	0.8	33	NSD	2.1	1.4	0.7
CV Harvest Method (%)		37.5	2.0	37.7	32.6	10.4	59.3	35.9
***P* (Irrig. Rate X Harvest Method Interaction)**		**0.105**	**0.275**	**0.086**	**0.204**	**<0.001**	**0.142**	**0.158**

Table 8. 2011 Euphorbia response to harvest method in Prowl-treated area. Southern Oregon Research & Extension Center, Central Point, OR.

Irrigation Rate	Harvest Method	Seed Yield (lb/ac)	Oil Content %	Oil Yield (lb/ac)	Percent Whole Pods	Plant Height (inch)	Final Stand (per ft^2) 1st Observation	Final Stand (per ft^2) 2nd Observation
High	Swathed	nm	nm	nm	nm	23.0	1.0	1.0
	Direct Combine	432	52.5	227	2.7	39.9	3.8	3.3
Low	Swathed	170	51.0	87	5.4	25.0	1.3	2.2
	Direct Combine	286	53.3	152	3.3	29.1	5.3	5.1
None	Swathed	146	52.1	76	7.3	19.5	1.4	1.6
	Direct Combine	166	52.9	88	2.7	23.8	3.3	2.8
Mean		252	52.8	133	3.4	29.5	3.2	3.0
***P* (Irrigation Rate)**		**<0.001**	**0.327**	**<0.001**	**0.337**	**<0.001**	**0.932**	**0.607**
LSD (0.05)-Irrigation Rate		99	NSD	50	NSD	2.4	NSD	NSD
CV Irrigation Rate (%)		23.4	1.6	24.9	38.2	13.2	44.9	36.5
***P* (Harvest Method)**		**0.817**	**0.158**	**0.788**	**0.008**	**0.081**	**0.069**	**0.081**
LSD (0.05)- Harvest Method		NSD	NSD	NSD	0.4	NSD	NSD	NSD
CV Harvest Method (%)		67.3	2.1	66.0	1.8	4.9	19.7	19.3
***P* (Irrig. Rate X Harvest Method Interaction)**		**0.422**	**0.037**	**0.385**	**0.220**	**0.179**	**0.502**	**0.249**

nm = not measured

Table 9. 2011 Euphorbia response to pre-plant herbicide in swathed area.
Southern Oregon Research & Extension Center, Central Point, OR.

Irrigation Rate	Herbicide Treatment	Seed Yield (lb/ac)	Oil Content %	Oil Yield (lb/ac)	Percent Whole Pods	Plant Height (inch)	Final Stand (per ft^2) 1st Observation	Final Stand (per ft^2) 2nd Observation
High	Prowl	nm	nm	nm	nm	23.0	1.0	1.0
	Sonalan	266	51.3	137	4.0	25.5	1.3	0.8
Low	Prowl	170	51.0	87	5.4	25.0	1.3	2.2
	Sonalan	184	51.4	95	5.4	25.5	2.4	2.0
None	Prowl	146	52.1	76	7.3	19.5	1.4	1.6
	Sonalan	105	52.0	55	5.7	23.4	1.3	1.3
Mean		182	51.6	94	5.2	24.4	1.6	1.4
***P* (Irrigation Rate)**		**<0.001**	**0.020**	**<0.001**	**0.003**	**0.259**	**0.023**	**<0.001**
LSD (0.05)-Irrigation Rate		65	0.4	30	0.9	NSD	0.4	0.4
CV Irrigation Rate (%)		19.9	1.2	20.5	20.0	11.5	32.4	30.5
***P* (Herbicide)**		**0.872**	**0.289**	**0.888**	**0.212**	**0.500**	**0.382**	**0.682**
LSD (0.05)- Herbicide		NSD	NSD	NSD	NSD	NSD	NSD	NSD
CV Herbicide (%)		23.9	0.4	24.6	14.4	4.7	40.2	74.8
***P* (Irrig. Rate X Herbicide Interaction)**		**0.361**	**0.408**	**0.342**	**0.572**	**0.388**	**0.075**	**0.937**

nm = not measured

Table 10. 2011 Euphorbia response to pre-plant herbicide in direct-combined area. Southern Oregon Research & Extension Center, Central Point, OR.

Irrigation Rate	Herbicide Treatment	Seed Yield (lb/ac)	Oil Content %	Oil Yield (lb/ac)	Percent Whole Pods	Plant Height (inch)	Final Stand (per ft^2) 1st Observation	Final Stand (per ft^2) 2nd Observation
High	Prowl	432	52.5	227	2.7	39.9	3.8	3.3
	Sonalan	424	52.2	197	3.1	35.5	4.5	3.5
Low	Prowl	286	53.3	152	3.3	29.1	5.3	5.1
	Sonalan	271	53.0	166	5.2	27.5	4.6	5.0
None	Prowl	166	52.9	88	2.7	23.8	3.3	2.8
	Sonalan	159	53.0	68	4.2	21.3	4.2	3.4
Mean		275	52.9	142	3.5	29.9	4.3	3.9
***P* (Irrigation Rate)**		**<0.001**	**0.101**	**<0.001**	**0.007**	**<0.001**	**0.616**	**0.305**
LSD (0.05)-Irrigation Rate		106	NSD	50	0.9	2.4	NSD	NSD
CV Irrigation Rate (%)		27.1	1.6	20.1	32.2	10.8	42.6	44.8
***P* (Herbicide)**		**0.862**	**0.758**	**0.118**	**0.030**	**0.245**	**0.834**	**0.829**
LSD (0.05)- Herbicide		NSD	NSD	NSD	1.2	NSD	NSD	NSD
CV Herbicide (%)		24.2	1.2	11.8	42.0	12.7	31.1	48.9
***P* (Irrig. Rate X Herbicide Interaction)**		**0.886**	**0.791**	**0.105**	**0.771**	**<0.001**	**0.864**	**0.778**