Research in the Klamath Basin
2011 Annual Report

Grindelia- A drought-tolerant, new domestic source of industrial resins for the Klamath Basin: 2011 Results

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Introduction

Background

Resinous compounds known as 'Naval Stores' were once used to caulk wooden ships, but now these compounds (including turpentine, fatty acids, rosins, and their derivatives) are used in large quantities by the papermaking industry(Thompson 1990; Hoffmann and McLaughlin 1986). These resins are incorporated into the liquid pulp or as a coating on the finished paper to improve color brilliance and ink permanence, while eliminating ink 'bleeding'. These compounds are also used in smaller amounts for producing rubber, chemicals, ester gums, and resins for many other specialty applications (i.e. rosin used on baseball bats and violin bows).

The primary current source for these resinous compounds is tapping old-growth pine trees, or by grinding up their stumps after logging. The complex chemical structure of these resins cannot be synthesized from petroleum or other simple oils. US consumption of these resins was fairly static from the 1960s until the 1990s at about 550,000 ton/yr, but in recent years the increased demand for fine paper for ink-jet, laser-

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jet, and copier applications as well as increased use of recycled paper have increased demand for paper sizing chemicals, including resins.

US production (which once met the demand) has nearly disappeared. In recent years, this need has been met by increased imports of resin primarily from China (60% of world production), Brazil (20%) and nearby countries. These supplies are potentially unreliable and expensive. About 60% of the world resin comes from tapping live trees (with the remainder from grinding up tree stumps after logging), and 70% of the live tree market is controlled by China. Since 1990, the price of gum resin has ranged between $0.20 and $1.13/lb, with a general upward trend. Price spikes have been more common in recent years. Except for these periodic price spikes, prices since 2000 have often been in the range of $0.36 to $0.54/lb.

In the early 1980s, it was discovered that *Grindelia camporum* and related species produce large quantities of a valuable diterpene resin (grindelic acid) that is nearly identical to the high quality resins from pine trees (Guerreiro et al. 1981; Bohlmann et al. 1982; McLaughlin and Hoffmann 1982; Timmermann et al. 1983). *G. camporum* is a perennial shrub, native of the western US, especially the central valley of California, and seems to grow well under non-irrigated conditions (Bailey 1976; Hoffmann et al. 1984; Hoffmann and McLaughlin 1986). In natural stands, grindelia seems to prefer soils higher in clay content, but this may be due to the greater water holding capacity of the soil in xeric climates rather than a preference for the drainage or texture of a clay soil *per se*. Diterpene resin acids constituted between 65 and 75% of the total crude resin in the plant (Hoffmann and McLaughlin 1986; McLaughlin 1986a, b). Studies on the heritability of resin production indicate that genetic improvement is feasible (Dunford 1964; McLaughlin 1986a, b; McLaughlin and Linker 1987).

In small, early tests in Arizona, experimental tetraploid lines of *G. camporum* yielded up to 5.6 ton/ac biomass per year, with a crude resin content of up to 11%, resulting in annual crude resin yields of up to 1,200 lb/ac, using between 22 and 30 inches of irrigation water (Hoffmann and McLaughlin 1986; McLaughlin and Linker 1987).

Although *G. camporum* received more initial interest than other species due to its greater size, later studies identified a South American native, *Grindelia chiloensis*, as also having commercial potential (Timmermann and Ravetta, 1990). For *G. camporum*, glands on the surface of flowers are responsible for most of the resin production, with little resin produced on the stems or leaves (Hoffmann et al. 1984). In contrast, *G. chiloensis* plants are typically smaller, but they have a large number of resin glands on all above-ground plant surfaces (flowers, leaves, and stems) and thus may also have potentially large resin production on a per acre basis. (Ravetta et al., 1996a and 1996b).

Future Prospects- Likely Production Areas

Due to reasons of weather and labor markets, China is unlikely to be able to rapidly increase their resin output if global markets expand, pointing towards likely upward resin price pressure in the future. Looking to the future, chemical companies have shown an increased interest in developing a stable, domestic source of these resins.

Grindelia (the generic term for both species) is likely suited to areas that are dry and warm. Deep soils would decrease the need for irrigation, as would presence of some clay. It is somewhat frost tolerant and a perennial, making it useful in temperate climates. Likely areas would include western US, western Australia, northern Africa, southern Europe, central China, and southern areas in South America. However, there may be differences in local adaptation that could favor production of either *G. camporum* or *G. chiloensis*, depending on the particular situation.

A brief economic analysis of grindelia's potential follows: If grindelia resin were conservatively valued at $0.30/lb, a biomass yield of 12 ton/ac with a crude resin yield of 1.2 ton/ac would be worth $720/ac. Due to resin extraction and processing costs, farm gate values for raw material would be estimated at 50%, or $360/ac. The likely reduced input costs would contribute to a farmer's net return from a grindelia crop (mainly due to reduced irrigation requirement) compared to other crops. Because grindelia is a perennial, establishment costs would be reduced, further adding to a farmer's net return (assuming good winter survival). Thus, the return could prove attractive in areas where the expense or lack of irrigation water limits other crops.

Recent Research

After the initial studies in the early to mid-1980s confirming grindelia's unusual ability to produce these resins, virtually no crop research was done until the mid-1990s when several small agronomic studies on *G. camporum* were begun by Dr. Roseberg at the Oregon State University Southern Oregon Research & Extension Center (SOREC) (Roseberg, 1996a). These studies, conducted in both sandy loam and clay soil types, showed grindelia could grow well and persist over multiple years in that climate. Overall, biomass yields ranged from 3.0 to 15.7 ton/ac, resulting in resin yields ranging from 750 to 3,940 lb/ac (Roseberg, 1996b).

***Grindelia camporum* (1995) and *G. chiloensis* (2000) near Medford Oregon.**

In the mid-1990s studies were also begun on *G. chiloensis* in Argentina by Dr. Damian Ravetta of the Universidad de Buenos Aires, focusing on wild plant collection, selection, plant physiology, and agronomic work (Ravetta et al., 1996b). In the late 1990s we also cooperated with Dr. Ravetta, comparing performance of the same *G. chiloensis* cultivars in Argentina and Oregon (Roseberg and Ravetta, 2003). Since then, Dr. Ravetta has continued with cultivar selection and improvement in Argentina, and now has several lines that appear more promising than those available in the late 1990s. He has also continued work on crop management aspects, such as N fertilization, air temperature, water use, response to light intensities, and related factors (Zavala and Ravetta, 2001; Wassner and Ravetta, 2005 and 2007).

No further research occurred in the US until 2010, when we received another small grant to resume studies through 2011 under the very different climate conditions found at KBREC. The South-Central Oregon region may be well suited to grindelia because it is sunnier, yet cooler than the Rogue Valley or California's central valley.

Results in Oregon suggest the possibility of achieving high biomass production without dramatically decreasing resin content. Despite grindelia's potential, many agronomic requirements of grindelia and their effects on yield and resin production are still unknown. The plant's resinous nature could make harvest with standard cutting equipment difficult. Commercial processing procedures need to be developed, and product development using grindelia biomass as a raw material is necessary also. Winter survival of both *G. camporum* and *G. chiloensis* may be more of an issue in the Klamath Basin, and both management and abiotic factors affecting survival of the various cultivars of both species are not well understood. Other crop management practices such as plant density, irrigation, etc. still need to be worked out for both *G. chiloensis* and *G. camporum*. We did some preliminary tests on seed germination requirements in the 1990s, as others also did earlier on (McLaughlin and Linker, 1987; Zafar et al., 1994), but have not yet developed dependable procedures for direct seeding in the field, as essentially all field research to date has been done with transplants.

Objectives

Given the many unknowns involved with domesticating grindelia into a viable commercial crop, based on limited funding resources we focused on the following objectives for 2010 and 2011 research trials at KBREC.

1. Evaluate growth, biomass yield, resin yield, and over-wintering persistence of several accessions of *G. chiloensis* and *G. camporum* in the Klamath Basin.

2. Evaluate response of *G. chiloensis* and *G. camporum* to various in plant density, irrigation rate, and nitrogen fertilization.

Summary of Procedures

For these trials, seed of five accessions of *G. chiloensis* was provided by Dr. Damian Ravetta from his germplasm collection at the University of Buenos Aires. In this report, these are designated as "ChXXX" indicating "Chiloensis" followed by the three digit accession number as denoted by Dr. Ravetta. Seed of eight accessions of *G.*

camporum was provided by Dr. Leslie Gunatilaka at the University of Arizona, Southwest Center for Natural Products, from the stored collection of retired University of Arizona scientist Steve McLaughlin. In this report, these are designated as “AXXX” indicating they were originally collected in Arizona, followed by the three digit accession number as denoted by Dr. McLaughlin. For simplicity, all these accessions will be referred to as “cultivars” of the two species throughout this report.

During the late winter of 2010, seed for all trials was started in flats in the greenhouse, and seedlings were transplanted to the field in spring 2010. Refer to our 2010 annual report for details of the first year of this study (Roseberg and Bentley, 2010). All trials were conducted at KBREC (Poe fine sandy loam). For each trial, weeds were controlled by mechanical and manual cultivation only. After initial irrigation of all plots to encourage uniform recovery from transplantation in 2010, irrigation rates were decided based on the Kimberly-Penman evapotranspiration (Et) calculated by the US Bureau of Reclamation Agricultural Meteorological (AgriMet) automated weather station located at KBREC (US Bureau of Reclamation, 2011), as described for each trial below. In the fall of 2011, above- ground biomass was cut near ground level by hand, air-dried, and then oven-dried for a week at 30^oC - 50^oC, and weighed. Sub samples were separated into the flower, stem, and leaf plant parts as described below. All samples are going to be shipped to Dr. Ravetta’s lab in Argentina for resin analysis when he is ready for them.

As described in the 2010 report, some plants were cut off at ground level and some were cut off approximately 8 inches above ground level in the fall of 2010 to measure the effect of harvest cutting height on winter survival and the subsequent year’s growth (Roseberg and Bentley, 2010). For each experiment and treatment, over-wintering survival rate and plant vigor was measured for each plant on May 27, 2011.

To measure the ratio of each plant part to the total biomass on a dry weight basis, and thus calculate total biomass on an oven-dry basis, the following procedures were used in each experiment described below.

For *G. chiloensis,* one whole plant was harvested from each plot and its flowers were cut off and separated into mature seedheads, mature flowers, or immature flowers. Each flower part was weighed wet and dry. The rest of the plant was weighed wet, then allowed to oven-dry at low heat (30^oC - 50^oC) until dry. When the whole plant was dry, leaves and stems were separated and each weighed dry.

After the one whole plant was taken from each plot for dissection, the rest of the plot was harvested and weighed wet to calculate total wet biomass yield. Total plot biomass yield was corrected to oven-dry weight based on the oven-dry proportion of the plant parts measured from the single dissected plant.

For *G. camporum*, one representative plant was selected and four typical stems were removed from it. All of the flowers were removed from the four stems and separated into mature seedhead, mature flowers, and immature flowers. Each flower part was weighed wet and dry. The stems (with leaves attached) were weighed wet and allowed to oven-dry at low heat (30°C - 50°C) until dry. When the four stems were dry, leaves and stems were separated and each weighed dry. The remaining portion of the whole plant (not including the four stems), as well as the remaining plants in each plot were weighed wet and discarded. Total plot biomass yield was corrected to oven-dry weight based on the oven-dry proportion of the plant parts measured from the four stems analyzed from the single dissected plant.

In addition to these biomass measurements, for both *G. chiloensis* and *G. camporum* we also measured the date of maximum flowering, the relative number of flowers per plant, the maximum proportion of flowers showing yellow petal color (a measure of maturity), and date when that maximum occurred. The oven-dry biomass of the single dissected plants was also calculated.

For each of the experiments described below, the dried plant parts from each plot (mature seedheads, mature flowers, immature flowers, leaves, and stems) will be shipped to Argentina later for resin analysis. Equipment problems, personnel issues, and international payment restrictions have delayed resin analysis, so resin data is not reported here. That data will be added to the report as soon as it is available and analyzed.

All measured parameters were analyzed statistically using SAS® for Windows, Release 9.1 (SAS Institute, Inc.) software. As appropriate, analysis of variance was calculated according to the 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. Plant Density x Cultivar Trials

Materials and Methods

Because *G. camporum* is typically a much larger plant than *G. chiloensesis*, the range of likely plant densities would not be equal in most cases. Because the two species' plant spacing treatments were usually not equivalent (and thus not directly comparable), statistics for the two species were analyzed separately.

One *G. camporum* (A173) and two *G. chiloensis* cultivars (Ch743 and Ch775) were transplanted in rows on June 23, 2010 (*G. camporum*) and July 6, 2010 (*G. chiloensis*), arranged to create four densities. The two *G. chiloensis* cultivars reportedly have similar plant architecture but different resin contents, which would allow us to evaluate how growth and resin yield may vary for high and low resin plants and plant parts as a function of plant density (Damian Ravetta, pers. comm., 2010). For *G. chiloensis*, the four between-row and within-row plant spacings were 12 x 30 inch; 12 x 20 inch; 12 x 12 inch; and 12 x 8 inch. The four between-row and within-row plant spacings for *G. camporum* were 30 x 60 inch, 30 x 30 inch, 12 x 30 inch, and 12 x 12 inch. For both species, each density treatment was replicated four times. Whenever possible, plants harvested for resin analysis or biomass were taken from the interior of a given plot to minimize edge effects. Thus, *G. camporum* data was analyzed as a randomized complete block design, and *G. chiloensis* data was analyzed as a complete factorial design, with cultivar and density as the two factors.

The entire Plant Density X Cultivar trial received irrigation equal to that applied to the 'medium' irrigation treatment of the irrigation response trial (Experiment II below) (Table 1). Thus, this trial received a total of 0.98 inches of rainfall plus 9.57 inches of irrigation from April 1 through October 15. All of the irrigation was applied on 9 dates in June, July, and August.

On September 23, individual leaves were collected from representative plants of each cultivar, within each irrigation block to allow calculation of mean surface area per leaf. On September 29 and 30, all *G. chiloensis* plots (both the individual plants for dissection and all remaining plants in each plot) were harvested, weighed wet, and processed for individual plant part dry weight determination as described above. The *G. camporum* plots were likewise harvested on October 11 and 17 prior to processing as described above.

Results and Discussion

Grindelia camporum

Neither plant spacing nor fall cutting height had a significant effect on winter survival or spring vigor for *G. camporum*, although survival generally tended to increase where fall cutting height was higher (Table 2). Winter survival of *G. camporum* was generally lower in this study than we had observed in earlier studies at SOREC (Roseberg and Ravetta, 2003).

For the *G. camporum* plants that survived the winter, plant spacing did not have a significant effect on any of the flowering measures, biomass yield per plant, or proportion of stem, leaf, or flower biomass, but there was a significant difference due to plant spacing for biomass per acre (Table 3). Thus for *G. camporum*, the biomass yield was controlled by the number of plants per acre rather than size of individual plants, suggesting that maximum plant density was not achieved in the second year, even though plants were much larger and clearly very crowded in 2011 compared to the establishment year (2010). This result was a bit surprising given the size and vigor of this species.

Unlike 2010, in 2011 many *G. camporum* plants went to flower, but none achieved mature seedheads, suggesting the season was not quite long enough to complete its life cycle.

Grindelia chiloensis

For *G. chiloensis*, plant spacing did not affect winter survival, but the effect of fall cutting height on winter survival was highly significant. No *G. chiloensis* plants that were cut at ground level survived the winter in this trial, whereas survival ranged from 2.5% to 12.5% when plants were cut at 8 inches from ground surface in the fall (Table 2).

For the *G. chiloensis* plants that survived the winter, plant spacing did not have a significant effect on any of the flowering measures or the proportion of stem, leaf, or flower biomass, but there was a significant difference due to plant spacing for biomass yield per plant and biomass per acre (Table 3). Despite the significance of biomass yield per plant due to plant spacing, the *G. chiloensis* biomass yield was primarily controlled by the number of plants per acre rather than size of individual plants, suggesting that maximum plant density was not achieved in the second year. This result was similar to that observed for *G. camporum*.

The effect of cultivar was not significant for any of the measured parameters. Unlike 2010, in 2011 many *G. chiloensis* plants went to flower, and some plants achieved mature seedheads.

It should be noted that individual plant biomass as well as biomass yield per acre in 2011 was approximately 10 times the biomass recorded in 2010 for both *G. camporum* and *G. chiloensis* (see Roseberg and Bentley, 2010), showing the dramatic increase in yield potential for these species once established (assuming winter survival).

II. Irrigation Rate x Cultivar Trials

Materials and Methods

As in the plant density x cultivar trial above, the two species were not inter-randomized and their statistics were analyzed separately.

Eight *G. camporum* (A086, A121, A153, A165, A170, A171, A173 and A175) and five *G. chiloensis* cultivars (Ch743, Ch775, Ch750, Ch766, and Ch734) were transplanted in replicated plots on June 23, 2010 (*G. camporum*) and July 6, 2010 (*G. chiloensis*). In some cases the number of plants per plot had to be adjusted due to limited number of plants for some cultivars. Among the *G. camporum* cultivars, only A173 had enough plants to allow replication (4 reps), but the *G. chiloensis* cultivars each were replicated from 2 to 4 times. Plant spacing was 30 x 30 inch for *G. camporum* and 12 x 20 inch for *G. chiloensis* in all cases (equal to the second widest spacing in the density x cultivar trial above).

In 2011, three irrigation rates were applied to separate blocks containing the replicated cultivar plots during the entire growing season. Thus, irrigation was applied at rates and times sufficient to keep cumulative irrigation plus precipitation at or just above 60% of calculated Et in the 'high' irrigation treatment, 40% of Et in the 'medium' irrigation treatment, and 20% of Et in the 'low' irrigation treatment. Data for both species was analyzed as a split plot design, with irrigation rate as the main plot and cultivar as the sub-plot. For *G. camporum*, the lack of plot replication for all but A173 prevented statistical comparison between cultivars.

As in the density x cultivar trial described above, on September 23, individual leaves were collected from representative plants of each cultivar within each irrigation block to allow calculation of mean surface are per leaf. On September 29 and 30, all *G. chiloensis* plots (both the individual plants for dissection and all remaining plants in each plot) were harvested, weighed wet, and processed for individual plant part dry weight determination as described above. The *G. camporum* plots were likewise harvested on October 11 and 17 prior to processing as described above.

Results and Discussion

Grindelia camporum

The effect of previous season irrigation on winter survival and spring vigor was not significant, but the effect of fall harvest cutting height was significant (Table 4). For most cultivars and irrigation rates, cutting at ground level reduced winter survival compared to cutting at 8 inches above ground level. Although analysis of variance could not be used to compare cultivar response due to lack of plot replication, some observations still stood out. Cultivar A153 almost always had 100% winter survival, whereas A171 usually had lower winter survival than the others. For some cultivars, previous season moisture stress seemed to improved winter survival, but in others this trend was not appear, thus the overall non-significance of differences due to the 2010 irrigation treatments.

Unlike survival, vigor ratings in spring 2011 were significantly affected by the previous season's irrigation, but not by the fall cutting height. Vigor was generally improved where previous season irrigation was greater, but cultivar response was variable and absolute vigor differences were small.

Of plants that survived the winter, irrigation rate did not have a significant effect on biomass yield per plant or on biomass yield per acre (Table 5). Although analysis of variance could not be used to compare cultivar response due to lack of plot replication, some observations still stood out. Cultivar A153 (which had exhibited excellent winter survival) consistently had the lowest biomass yield. Plants in general grew well even in the 'low' irrigation treatment, although increased irrigation did seem to increase yield somewhat for some cultivars. Biomass yields were good overall, and were similar to those observed in previous studies at SOREC. Differences in flower timing and numbers due to irrigation were not significant, but there were significant differences in the proportion of plant parts due to irrigation treatment except for percent immature flowers. Increased irrigation generally resulted in a higher proportion of mature seedheads, mature flowers, and stem, but a lower proportion of leaf.

Without replication we cannot make firm conclusions about cultivar differences. The cultivar that has been tested most commonly over the years (A173) performed well in this group, but based on these second year results, others such as A171 and A121 deserve further evaluation.

Grindelia chiloensis

The effect of previous season irrigation on winter survival and spring vigor was not significant, but the effect of fall harvest cutting height and cultivar were both significant for survival (Table 4). Cutting at ground level was clearly detrimental to *G. chiloensis* survival, as very few plants survived under any conditions. The cultivar Ch750 had consistently higher survival than the others. Differences in spring vigor were not significant for previous season irrigation rate or cultivar, and so few survived the ground level cutting treatment that vigor comparisons between cutting heights was not possible using analysis of variance.

Of plants that survived the winter, neither irrigation rate nor cultivar had a significant effect on biomass yield per plant or on biomass yield per acre (Table 5). Biomass yields were generally good compared to previous studies at SOREC, although winter survival was poorer overall.

Differences in plant part proportion were also not significant for either irrigation rate or cultivar. The date of maximum flower abundance was significantly affected by irrigation rate (and was nearly significant for cultivar at P=0.051). In almost every case, the ‘medium’ irrigation treatment resulted in later timing of maximum flowering.

Similar to results described for Experiment I above, in Experiment II the individual plant biomass as well as biomass yield per acre in 2011 for both *G. camporum* and *G. chiloensis* was approximately 10 times the biomass recorded in 2010 (see Roseberg and Bentley, 2010), showing the dramatic increase in yield potential for these species once established (assuming winter survival).

III. Nitrogen Rate x Cultivar Trials

Materials and Methods

A trial designed to measure grindelia’s response to nitrogen fertilizer was also set up and transplanted in early summer, 2010. This trial included one *G. camporum* cultivar (A173) and two *G. chiloensis* cultivars (Ch743 and Ch775). The N fertilizer treatments were not applied to this trial in 2010 due to the overall small plant size for both species by mid-summer. It was decided to postpone these treatments until the 2011 growing season to measure the impact of N on larger (higher yielding) plants which we expected to observe in the second year (2011).

The nitrogen treatments were applied on June 1. In the control treatment plots (N_0), no fertilizer was applied. For the N_{50} treatment plots, prilled urea was top-dressed by hand to supply 50 lb/ac N and was dissolved into the soil by sufficient rainfall very soon after application.

The entire Nitrogen Rate X Cultivar trial received irrigation equal to that applied to the ‘medium’ irrigation treatment of the irrigation response trial (Experiment II above) in both 2010 and 2011 (Table 1). Thus, this trial received a total of 0.98 inches of rainfall plus 9.57 inches of irrigation from April 1 through October 15. All of the irrigation was applied on 9 dates in June, July, and August. The data was analyzed as a split plot design, with cultivar as the main plot and nitrogen rate as the sub-plot.

On September 23, individual leaves were collected from representative plants of each cultivar, within each irrigation block to allow calculation of mean surface area per leaf. On September 29, all *G. chiloensis* plots (both the individual plants for dissection and all remaining plants in each plot) were harvested, weighed wet, and processed for individual plant part dry weight determination as described above. The *G. camporum* plots were likewise harvested on October 11 and 17 prior to processing as described above.

Results and Discussion

Because the plots did not receive the N treatments until June 1, 2011, the overwintering survival and vigor ratings made on May 27, 2011 obviously do not reflect any effect of the fertilizer treatment, but only the effects of cultivar and cutting height the previous fall (Table 6). There was a significant cultivar effect on winter survival, mainly that *G. camporum* survival was much better than each cultivar of *G. chiloensis*. Even though the effect of cutting height on survival was not significant, this was mainly due to the similar survival rate of *G. camporum* at both cutting heights. For *G. chiloensis*, it appeared cutting at ground level reduced winter survival, but survival was poor overall for *G. chiloensis* in this trial.

Of plants that survived the winter, the nitrogen fertilizer treatment had no significant effect on any of the growth or yield parameters measured (Table 7). Differences between cultivars were significant for most parameters. The *G. camporum* cultivar produced higher yield than either *G. chiloensis* cultivar, but *G. chiloensis* yields were fairly good in this trial. As expected, G. *camporum* had a higher proportion of stem biomass, but both *G. chiloensis* cultivars had a higher proportion of leaf biomass. The *G. chiloensis* cultivars both flowered earlier than *G. camporum.*

Overall Summary

Biomass yields in 2011 were approximately ten times those observed in 2010, highlighting the importance of over-winter survival and second year growth to the overall yield potential of this crop. Biomass yield per acre was primarily controlled by plant density, with very small to no difference in biomass yield per plant regardless of spacing for a given cultivar. Grindelia grew well even under the ‘low’ irrigation treatment, and while some additional irrigation seemed to improve *G. camporum*’s growth somewhat in the first year, irrigation rate did not seem to affect yield in the second year. Some less-studied *G. camporum* cultivars deserve further investigation. Adding nitrogen fertilizer (at 50 lb/ac N) did not affect growth or yield in any way. Fall cutting height management seemed to affect overwinter survival for both species, but cutting at ground level was especially detrimental to survival of *G. chiloensis*.

Once the resin data are available, more definitive recommendations as to favored plant spacing, irrigation, and cultivar should be possible for both *G. camporum* and *G. chiloensis*. Overwintering survival and yield data showed that fall harvest management and cultivar differences both had a significant role in winter survival for both species. It may be that Klamath Basin winters are too cold for economic production unless specific cultivars and management practices are used. Based on this preliminary data it appears the grindelia may have a place in the Klamath Basin under conditions of limited irrigation, but further investigation is necessary to either validate or disprove this tentative conclusion before commercialization can become a reality.

Acknowledgements

Special thanks to the following cooperators for their assistance with this research:

Damian Ravetta, Universidad de Buenos Aires, Argentina for providing the *G. chiloensis* seed and for performing resin analysis on harvested plant samples.

Dr. Leslie Gunatilaka (University of Arizona, Southwest Center for Natural Products), and Dr. Steve McLaughlin (University of Arizona, retired) for providing the *G. camporum* seed.

Partial funding for this research was provided by Agricultural Research Foundation Grant #ARF 7314.

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Table 1. 2011 Precipitation & irrigation for the grindelia irrigation rate x cultivar trial.
Klamath Basin Research & Extension Center, Klamath Falls, OR.

Month	Precipitation (inch)	"Wet" Block		"Medium" Block		"Dry" Block	
		Irrigation (inch)	Irrigation Applications	Irrigation (inch)	Irrigation Applications	Irrigation (inch)	Irrigation Applications
April	1.46	0.00	0	0.00	0	0.00	0
May	0.81	0.00	0	0.00	0	0.00	0
June	0.14	5.94	3	2.97	2	1.98	1
July	0.29	3.63	4	3.63	4	0.66	1
August	0.00	4.95	5	2.97	3	1.98	2
September	0.02	0.00	0	0.00	0	0.00	0
Oct. 1-15	0.53	0.00	0	0.00	0	0.00	0
Total	**0.98**	**14.52**	**12**	**9.57**	**9**	**4.62**	**4**

Table 2. 2011 *Grindelia camporum* & *Grindelia chiloensis* winter survival & spring vigor as affected by fall harvest cutting height. Klamath Basin Research & Extension Center, Klamath Falls, OR.

***Grindelia camporum, cultivar* A173**			
Fall Cut Height	**Plant Spacing**	**Winter Survival (%)**	**Spring Vigor[1]**
Short	12x12	25.2	1.4
	12x30	16.0	1.6
	30x30	37.8	1.3
	30x60	34.5	1.3
Tall	12x12	18.8	1.5
	12x30	37.5	1.1
	30x30	50.0	1.2
	30x60	50.0	1.3
Mean		33.7	1.3
***P* (Spacing)**		**0.191**	**0.836**
LSD (0.05)- Spacing		NSD	NSD
***P* (Cut Height)**		**0.215**	**0.512**
LSD (0.05)- Cut Height		NSD	NSD
***P* (Spacing X Cut Height Interaction)**		**0.674**	**0.635**
CV (%)		70.4	29.7

[1] Vigor rated on a relative scale: 0= dead, 1= alive, but weak to moderate vigor, 2= growing with strong vigor.

***Grindelia chiloensis, cultivars* Ch743 & Ch775**				
Cultivar	**Height**	**Plant Spacing**	**Winter Survival (%)**	**Spring Vigor[1]**
Ch743	Short	12x8	0.0	nm[2]
		12x12	0.0	nm[2]
		12x20	0.0	nm[2]
		12x30	0.0	nm[2]
Ch775	Short	12x8	0.0	nm[2]
		12x12	0.0	nm[2]
		12x20	0.0	nm[2]
		12x30	0.0	nm[2]
Ch743	Tall	12x8	7.3	1.5
		12x12	6.8	1.8
		12x20	10.6	2.0
		12x30	6.8	0.8
Ch775	Tall	12x8	2.5	2.0
		12x12	12.5	2.0
		12x20	7.0	1.0
		12x30	7.7	1.8
Mean			3.8	1.4
***P* (Cultivar)**			**0.899**	**0.596**
LSD (0.05)- Cultivar			NSD	NSD
***P* (Spacing)**			**0.783**	**0.273**
LSD (0.05)- Spacing			NSD	NSD
***P* (Cut Height)**			**<0.001**	**nm[2]**
LSD (0.05)- Cut Height			3.5	nm[2]
***P* (Cultivar x Spacing Interaction)**			**0.712**	**0.049**
***P* (Spacing X Cut Height Interaction)**			**0.783**	**nm[2]**
***P* (Cultivar X Cut Height Interaction)**			**0.899**	**nm[2]**
***P* (Cultivar x Spacing x Cut Height Interaction)**			**0.712**	**nm[2]**
CV (%)			183.1	30.9

[1] Vigor rated on a relative scale: 0= dead, 1= alive, but weak to moderate vigor, 2= growing with strong vigor.

[2] nm = Not measured due to lack of vigor ratings for plants receiving "short" fall cutting treatment (none survived the winter).

Table 3. 2011 crop growth and biomass yield of *Grindelia camporum* & *Grindelia chiloensis* cultivars as affected by plant spacing. Klamath Basin Research & Extension Center, Klamath Falls, OR.

Grindelia camporum, cultivar A173											
	Maximum Color Showing		Maximum Flower Rating[1]		Biomass Yield						
Plant Spacing	(%)	Date	(%)	Date	% Mature Seedheads	% Immature Flowers	% Mature Flowers	% Leaf	% Stem	Total (ton/ac O.D.)	Plant Mass (g/plant)
12x12	6.8	266.0	2.6	237.5	0.0	2.1	0.7	33.7	63.5	60.63	1706
12x30	5.2	266.0	2.6	222.0	0.0	2.3	0.2	30.5	67.0	25.78	1624
30x30	5.8	256.5	2.5	241.8	0.0	3.6	1.3	31.3	63.7	13.94	1573
30x60	10.6	266.0	2.7	235.5	0.0	4.3	1.9	27.8	66.0	8.71	2311
Mean	7.2	263.5	2.6	235.0	0.0	3.1	1.1	30.9	64.9	27.37	1815
***P* Value**	**0.273**	**0.487**	**0.927**	**0.634**	**nc[2]**	**0.539**	**0.206**	**0.555**	**0.790**	**0.006**	**0.525**
LSD (0.05)	NSD	NSD	NSD	NSD	nc[2]	NSD	NSD	NSD	NSD	26.0	NSD
CV (%)	53.3	3.6	18.8	7.9	nc[2]	74.7	95.7	18.4	7.4	56.1	42.9

[1] Flowering rated on a relative scale: 0= none, 1= few, 2= some, 3= many.

[2] nc = Not calculated due to all values equalling zero or missing data.

Grindelia chiloensis, cultivars Ch743 & Ch775												
		Maximum Color Showing		Maximum Flower Rating[1]		Biomass Yield						
Cultivar	Plant Spacing	(%)	Date	(%)	Date	% Mature Seedheads	% Immature Flowers	% Mature Flowers	% Leaf	% Stem	Total (ton/ac O.D.)	Plant Mass (g/plant)
Ch743	12x8	92.5	211.5	3.0	201.5	3.4	0.2	0.0	57.2	39.3	22.46	374
	12x12	100.0	225.5	2.8	205.5	5.1	0.3	0.6	54.9	39.1	11.08	205
	12x20	97.5	219.0	3.0	195.0	5.2	0.0	0.0	55.3	39.5	9.55	342
	12x30	97.5	219.0	2.5	201.5	3.2	0.0	0.5	61.6	34.8	3.33	173
Ch775	12x8	90.0	223.0	2.5	215.0	4.2	0.8	2.7	51.1	41.3	23.36	500
	12x12	88.8	219.0	3.0	198.0	7.6	0.3	0.5	55.2	36.4	20.66	599
	12x20	68.8	220.3	2.0	190.3	2.4	0.7	0.5	66.2	30.1	4.31	150
	12x30	73.8	225.5	3.0	191.5	8.0	1.9	5.9	44.7	39.5	6.69	438
Mean		86.2	220.2	2.6	198.3	4.7	0.6	1.2	57.0	36.5	11.55	324
***P* (Cultivar)**		**0.189**	**0.270**	**0.473**	**0.437**	**0.733**	**0.141**	**0.079**	**0.876**	**0.277**	**0.339**	**0.244**
LSD (0.05)- Cultivar		NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD
***P* (Spacing)**		**0.922**	**0.328**	**0.800**	**0.558**	**0.505**	**0.606**	**0.069**	**0.291**	**0.585**	**0.002**	**0.032**
LSD (0.05)- Spacing		NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	8.4	162
***P* (Cultivar X Spacing Interaction)**		**0.926**	**0.170**	**0.562**	**0.686**	**0.539**	**0.611**	**0.230**	**0.262**	**0.485**	**0.151**	**0.012**
CV (%)		33.9	2.2	32.4	6.5	76.5	156.5	140.5	15.5	17.6	37.1	31.4

[1] Flowering rated on a relative scale: 0= none, 1= few, 2= some, 3= many.

Table 4. 2011 *Grindelia camporum* & *Grindelia chiloensis* winter survival & spring vigor as affected by fall harvest cutting & prior season irrigation rate. Klamath Basin Research & Extension Center, Klamath Falls, OR.

Grindelia camporum cultivars				
Irrigation Rate	**Fall Cut Height**	**Cultivar**	**Winter Survival (%)**	**Spring Vigor[1]**
High	Short	A086	50.0	1.8
		A121	0.0	nm[2]
		A153	100.0	2.0
		A165	25.0	1.5
		A170	12.5	2.0
		A171	16.7	1.0
		A173	24.0	1.6
		A175	33.3	2.0
	Tall	A086	75.0	1.7
		A121	66.7	2.0
		A153	100.0	2.0
		A165	75.0	1.7
		A170	50.0	2.0
		A171	33.3	2.0
		A173	47.9	1.5
		A175	33.3	2.0
Medium	Short	A086	0.0	nm[2]
		A121	50.0	1.0
		A153	100.0	2.0
		A165	75.0	1.3
		A170	0.0	nm[2]
		A171	100.0	1.0
		A173	34.4	1.2
		A175	0.0	nm[2]
	Tall	A086	0.0	nm[2]
		A121	0.0	nm[2]
		A153	0.0	nm[2]
		A165	100.0	1.0
		A170	100.0	1.0
		A171	0.0	nm[2]
		A173	37.5	1.3
		A175	0.0	nm[2]
Low	Short	A086	37.5	1.0
		A121	50.0	1.3
		A153	100.0	1.9
		A165	0.0	nm[2]
		A170	40.0	1.0
		A171	16.7	2.0
		A173	53.1	1.5
		A175	16.7	1.0
	Tall	A086	0.0	nm[2]
		A121	100.0	1.7
		A153	100.0	2.0
		A165	25.0	1.0
		A170	66.7	2.0
		A171	33.3	1.0
		A173	87.5	1.7
		A175	33.3	1.0
Mean			44.7	1.5
***P* (Irrigation)**			**0.134**	**0.019**
LSD (0.05)- Irrigation			NSD	0.4
CV Irrigation (%)			63.4	16.1
***P* (Cultivar)**			**nc[3]**	**nc[3]**
LSD (0.05)- Cultivar			nc[3]	nc[3]
CV Cultivar (%)			nc[3]	nc[3]
***P* (Cut Height)**			**0.015**	**0.456**
LSD (0.05)- Cut Height			9.4	NSD
CV Cut Height (%)			37.8	22.2
***P* (Irrigation x Cultivar Interaction)**			**nc[3]**	**nc[3]**
***P* (Irrigation x Cut Height Interaction)**			**0.012**	**0.805**
***P* (Cultivar x Cut Height Interaction)**			**0.018**	**0.929**
***P* (Irrigation x Cultivar x Cut Height Interaction)**			**0.060**	**0.144**

[1] Vigor rated on a relative scale: 0= dead, 1= alive, but weak to moderate vigor, 2= growing with strong vigor.

[2] nm = Not measured due to lack of vigor ratings if no plants survived the winter.

[3] nc = Not calculated due to non-replication of most cultivars.

Grindelia chiloensis cultivars				
Irrigation Rate	**Fall Cut Height**	**Cultivar**	**Winter Survival (%)**	**Spring Vigor[1]**
High	Short	Ch743	0.0	nm[2]
		Ch775	0.0	nm[2]
		Ch750	0.0	nm[2]
		Ch766	0.0	nm[2]
		Ch734	0.0	nm[2]
	Tall	Ch743	2.3	1.0
		Ch775	0.0	nm[2]
		Ch750	30.4	1.8
		Ch766	0.0	nm[2]
		Ch734	20.0	1.5
Medium	Short	Ch743	0.0	nm[2]
		Ch775	0.0	nm[2]
		Ch750	50.0	2.0
		Ch766	0.0	nm[2]
		Ch734	0.0	nm[2]
	Tall	Ch743	10.6	2.0
		Ch775	7.0	1.0
		Ch750	40.9	1.8
		Ch766	0.0	nm[2]
		Ch734	0.0	nm[2]
Low	Short	Ch743	0.0	nm[2]
		Ch775	0.0	nm[2]
		Ch750	0.0	nm[2]
		Ch766	0.0	nm[2]
		Ch734	0.0	nm[2]
	Tall	Ch743	4.5	1.5
		Ch775	25.0	2.0
		Ch750	60.5	1.7
		Ch766	0.0	nm[2]
		Ch734	20.0	2.0
Mean			9.8	1.7
***P* (Irrigation)**			**0.449**	**0.092**
LSD (0.05)- Irrigation			NSD	NSD
CV Irrigation (%)			203.1	15.8
***P* (Cultivar)**			**0.006**	**0.477**
LSD (0.05)- Cultivar			13.6	NSD
CV Cultivar (%)			186.1	22.2
***P* (Cut Height)**			**<0.001**	**nc[3]**
LSD (0.05)- Cut Height			4.3	nc[3]
CV Cut Height (%)			93.1	nc[3]
***P* (Irrigation x Cultivar Interaction)**			**0.752**	**0.265**
***P* (Irrigation x Cut Height Interaction)**			**0.010**	**nc[3]**
***P* (Cultivar x Cut Height Interaction)**			**0.006**	**nc[3]**
***P* (Irrigation x Cultivar x Cut Height Interaction)**			**0.005**	**nc[3]**

[1] Vigor rated on a relative scale: 0= dead, 1= alive, but weak to moderate vigor, 2= growing with very strong vigor.

[2] nm = Not measured due to lack of vigor ratings if no plants survived the winter.

[3] nc = Not calculated due to non-replication or no data for vigor where no plants survived the winter.

Table 5. 2011 crop growth & biomass yield of *Grindelia camporum* & *Grindelia chiloensis* cultivars as affected by irrigation rate. Klamath Basin Research & Extension Center, Klamath Falls, OR.

Grindelia camporum cultivars												
		Maximum Color Showing		Maximum Flower Rating[1]		Biomass Yield						
Irrigation Rate	Cultivar	(%)	Date	(%)	Date	% Mature Seedheads	% Immature Flowers	% Mature Flowers	% Leaf	% Stem	Total (ton/ac O.D.)	Plant Mass (g/plant)
High	A086	11.4	266.0	2.6	266.0	0.0	7.6	3.4	20.0	69.0	18.50	370
	A121	12.5	266.0	3.0	228.0	0.0	8.5	3.4	26.0	62.0	27.36	713
	A153	85.0	228.0	3.0	258.0	55.8	0.0	3.3	12.3	28.6	8.82	108
	A165	30.0	266.0	1.6	223.0	3.6	4.6	20.3	22.2	49.4	15.79	350
	A170	0.0	nm[2]	1.7	266.0	0.0	0.9	0.0	30.7	68.4	18.21	559
	A171	0.0	nm[2]	2.0	258.0	0.0	5.9	0.8	27.2	66.1	17.80	484
	A173	8.2	264.0	2.9	287.0	0.0	4.4	1.7	28.2	65.6	18.38	514
	A175	0.0	nm[2]	2.0	266.0	0.0	0.0	0.0	36.3	63.7	17.00	617
Medium	A086	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]
	A121	10.0	226.0	3.0	215.0	0.0	3.0	2.5	31.3	63.1	26.29	824
	A153	92.5	228.0	4.0	258.0	42.1	0.0	0.0	14.4	43.5	9.46	137
	A165	3.3	266.0	2.3	228.0	0.6	3.4	3.9	27.7	64.5	8.78	243
	A170	0.0	nm[2]	3.0	266.0	0.0	5.3	0.0	29.3	65.4	15.09	442
	A171	0.0	nm[2]	2.0	266.0	0.0	1.3	0.0	33.0	65.7	16.43	543
	A173	5.8	256.5	2.5	241.8	0.0	3.6	1.3	31.3	63.7	13.94	413
	A175	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]
Low	A086	10.0	266.0	3.0	223.0	0.0	4.5	2.6	34.3	58.6	6.91	237
	A121	12.5	266.0	2.5	215.0	0.0	2.0	0.5	26.4	71.2	13.54	358
	A153	80.0	235.0	4.0	258.0	51.7	0.0	0.0	16.2	32.2	1.26	20
	A165	55.0	266.0	3.0	208.0	0.0	10.6	5.6	31.8	52.0	5.14	164
	A170	0.0	nm[2]	2.5	266.0	0.0	5.3	1.9	56.3	36.6	16.40	923
	A171	15.0	258.0	3.0	258.0	0.0	0.6	0.0	48.5	50.9	35.00	1696
	A173	9.4	262.0	2.7	247.0	0.0	5.3	2.4	30.7	61.7	15.88	483
	A175	5.0	223.0	1.5	223.0	0.0	2.2	0.0	42.7	55.2	10.52	
Mean		16.6	255.6	2.7	250.1	5.0	3.8	2.3	29.9	59.0	15.52	480
***P* (Irrigation)**		**0.410**	**0.705**	**0.883**	**0.273**	**<0.001**	**0.758**	**0.045**	**0.016**	**0.014**	**0.252**	**0.207**
LSD (0.05)- Irrigation		NSD	NSD	NSD	NSD	0.1	NSD	1.1	6.9	3.5	NSD	NSD
CV Irrigation (%)		33.4	3.5	15.0	14.7	8.5	74.2	74.4	6.8	5.3	26.7	22.8
***P* (Cultivar)**		**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**
LSD (0.05)- Cultivar		nc[3]	nc[3]	nc[3]	nc[3]	nc[3]	nc[3]	nc[3]	nc[3]	nc[3]	nc[3]	nc[3]
CV Cultivar (%)		nc[3]	nc[3]	nc[3]	nc[3]	nc[3]	nc[3]	nc[3]	nc[3]	nc[3]	nc[3]	nc[3]
***P* (Irrigation x Cultivar Interaction)**		**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**

[1] Flowering rated on a relative scale: 0= none, 1= few, 2= some, 3= many.

[2] nm = Not measured due to lack of data or if no plants survived the winter.

[3] nc = Not calculated due to non-replication or no data where no plants survived or none flowered.

Grindelia chiloensis cultivars												
		Maximum Color Showing		Maximum Flower Rating[1]		Biomass Yield						
Irrigation Rate	Cultivar	(%)	Date	(%)	Date	% Mature Seedheads	% Immature Flowers	% Mature Flowers	% Leaf	% Stem	Total (ton/ac O.D.)	Plant Mass (g/plant)
High	Ch743	90.0	215.0	2.0	188.0	1.7	1.8	4.0	49.9	42.7	5.81	202
	Ch775	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]
	Ch750	93.6	225.5	3.0	193.0	7.8	0.3	2.1	51.3	38.4	9.17	395
	Ch766	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]
	Ch734	97.5	228.0	3.0	188.0	8.3	0.5	0.0	53.0	38.2	6.43	302
Medium	Ch743	97.5	219.0	3.0	195.0	5.2	0.0	0.0	55.3	39.5	9.55	342
	Ch775	68.8	220.3	2.0	190.3	2.5	0.7	0.5	66.2	30.1	4.31	150
	Ch750	50.3	231.5	3.0	251.5	12.8	0.0	0.0	50.0	37.3	6.88	271
	Ch766	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]
	Ch734	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]
Low	Ch743	95.0	219.0	3.0	188.0	5.9	0.9	5.0	47.2	41.0	5.67	315
	Ch775	95.0	215.0	3.0	188.0	10.3	1.5	6.2	55.1	27.0	15.92	553
	Ch750	81.7	219.0	2.9	193.0	15.8	1.0	2.7	42.3	38.3	8.04	313
	Ch766	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]
	Ch734	92.5	219.0	3.0	188.0	9.6	0.2	1.0	53.2	36.0	12.58	301
Mean		83.9	221.5	2.8	196.5	8.3	0.6	1.9	52.5	36.6	7.98	302
***P* (Irrigation)**		**0.327**	**0.094**	**0.567**	**0.005**	**0.236**	**0.354**	**0.161**	**0.280**	**0.692**	**0.233**	**0.777**
LSD (0.05)- Irrigation		NSD	NSD	NSD	9.4	NSD	NSD	NSD	NSD	NSD	NSD	NSD
CV Irrigation (%)		27.4	2.6	19.2	7.1	87.6	227.9	183.4	26.1	14.6	39.5	47.3
***P* (Cultivar)**		**0.730**	**0.230**	**0.793**	**0.051**	**0.081**	**0.226**	**0.125**	**0.466**	**0.234**	**0.421**	**0.603**
LSD (0.05)- Cultivar		NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD
CV Cultivar (%)		46.4	2.2	21.9	4.2	31.8	130.8	114.6	17.5	15.4	24.5	26.6
***P* (Irrigation x Cultivar Interaction)**		**0.888**	**0.471**	**0.673**	**0.066**	**0.384**	**0.996**	**0.395**	**0.994**	**0.861**	**0.031**	**0.104**

[1] Flowering rated on a relative scale: 0= none, 1= few, 2= some, 3= many.

[2] nm = Not measured due to lack of data or if no plants survived the winter.

[3] nc = Not calculated due to non-replication or no data where no plants survived or none flowered.

Table 6. 2011 *Grindelia camporum* & *Grindelia chiloensis* winter survival & spring vigor as affected by fall harvest cutting. Klamath Basin Research & Extension Center, Klamath Falls, OR. Used *Grindelia camporum cultivar* A173 & *Grindelia chiloensis* cultivars Ch743 & Ch775.

Cultivar	Fall Cut Height	Winter Survival (%)	Spring Vigor[1]
A173	Short	46.9	1.4
	Tall	31.3	1.4
Ch743	Short	0.0	nm[2]
	Tall	4.3	1.8
Ch775	Short	0.0	nm[2]
	Tall	10.6	2.0
Mean		15.5	1.5
***P* (Cultivar)**		**<0.001**	**0.207**
LSD (0.05)- Cultivar		14.6	NSD
CV Cultivar (%)		124.4	16.8
***P* (Cut Height)**		**0.969**	**0.730**
LSD (0.05)- Cut Height		NSD	NSD
CV Cut Height (%)		132.1	29.9
***P* (Cultivar x Cut Height Interaction)**		**0.192**	**nc[3]**

[1] Vigor rated on a relative scale: 0= dead, 1= alive, but weak to moderate vigor, 2= growing with strong vigor.

[2] nm = Not measured due to lack of vigor ratings if no plants survived the winter.

[3] nc = Not calculated due to non-replication or no data for vigor where no plants survuved the winter.

Table 7. 2011 Crop growth & biomass yield of *Grindelia camporum* & *Grindelia chiloensis* as affected by nitrogen fertilization. Klamath Basin Research & Extension Center, Klamath Falls, OR. Used *Grindelia camporum cultivar* A173 & *Grindelia chiloensis* cultivars Ch743 & Ch775.

Cultivar	N Fertilizer Rate (lb N/ac)	Maximum Color Showing		Maximum Flower Rating[1]		Biomass Yield						
		(%)	Date	(%)	Date	% Mature Seedheads	% Immature Flowers	% Mature Flowers	% Leaf	% Stem	Total (ton/ac O.D.)	Plant Mass (g/plant)
A173	50	8.0	262.0	2.8	232.2	0.3	3.8	3.6	26.2	66.2	16.18	2065
	None	11.8	264.0	3.0	250.5	0.0	5.9	2.0	28.2	63.8	14.99	1936
Ch743	50	100.0	223.0	2.5	188.0	2.4	0.0	1.1	59.9	36.5	10.92	494
	None	100.0	223.0	3.0	188.0	6.2	0.9	0.6	55.8	36.6	5.22	181
Ch775	50	96.7	217.7	3.0	199.7	9.1	0.4	0.6	54.1	35.9	10.00	381
	None	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]	nm[2]
Mean		47.8	244.7	2.9	221.0	3.1	3.0	1.9	39.4	52.7	12.58	1286
***P* (Cultivar)**		**<0.001**	**<0.001**	**0.275**	**0.052**	**0.026**	**0.004**	**0.067**	**0.016**	**0.008**	**0.016**	**0.017**
LSD (0.05)- Cultivar		45.0	22.6	NSD	42.2	6.9	2.2	NSD	15.0	14.5	4.20	850
CV Cultivar (%)		7.1	0.9	10.5	7.8	88.7	22.3	65.7	18.5	10.3	18.3	36.9
***P* (N Rate)**		**0.397**	**0.391**	**0.391**	**0.192**	**0.391**	**0.389**	**0.453**	**0.565**	**0.397**	**0.747**	**0.886**
LSD (0.05)- N Rate		NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD
CV N Rate (%)		11.3	1.2	12.2	7.0	12.1	96.8	131.4	11.5	6.3	38.0	91.7
***P* (Cultivar x N Rate Interaction)**		**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**	**nc[3]**

[1] Flowering rated on a relative scale: 0= none, 1= few, 2= some, 3= many.

[2] nm = Not measured due to lack of data if no plants survived the winter.

[3] nc = Not calculated due to non-replication or no data where no plants survived the winter.