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Title: The Effects of Paclobutrazol and Uniconazol on Red Clover Seed Production.

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Excessive growth by red clover, *Trifolium pratense* L., grown for seed interferes with maximum seed production and harvest in Oregon's Willamette Valley. This study was conducted during 1986 and 1987 on red clover cv. Kenland to determine if plant height and dry matter production could be inhibited and seed yields improved with the plant growth regulators (PGRs) uniconazol (XE-1019) and paclobutrazol (Parlay). The effects of different soil-applied and foliar-applied PGRs and application rates on plant height, crop biomass, and yield components of red clover were measured at Corvallis, OR on Woodburn silt-loam (fine-silty mixed mesic Aquultic Argixerolls) soil. Soil-applied PGRs were also managed under single and multiple irrigation regimes in 1986.

Under a single irrigation regime in 1986, canopy height was reduced by 32% when XE-1019 was applied at 1.12 kg ai/ha and was reduced by 13% when Parlay was applied at 1.68 kg ai/ha. Averaged over the two-year period, straw yield was reduced 40% with XE-1019 (1.12 kg ai/ha) and by 12% with Parlay (1.68 kg ai/ha). Seed yield was increased by 11% with the lower XE-1019 rate (0.14 kg ai/ha) and was increased by 14% with the higher Parlay rate (1.68 kg ai/ha). Soil-applied PGR treatments reduced canopy height by 25% with XE-1019 (1.12 kg ai/ha) and was

reduced by 11% with Parlay (1.68 kg ai/ha) under multiple irrigation in 1986. Straw yield was reduced by 30% with XE-1019 (0.84 kg ai/ha), but Parlay had no effect on straw yield. In addition, seed yield was increased by 8% with XE-1019 (0.56 kg ai/ha) and by 18% with Parlay (1.68 kg ai/ha).

Foliar-applied XE-1019 (1.12 kg ai/ha) reduced canopy height by 13% in 1986 and by 25% in 1987, whereas foliar-applied Parlay (1.12 kg ai/ha) reduced canopy height by 9% in 1986 and by 19% in 1987. In 1986, seed yield increases averaged 16% across all XE-1019 treatments (0.07 to 1.12 kg ai/ha) and was increased an average of 21% across all Parlay treatments (0.28 to 1.68 kg ai/ha). However, 1987 was drier and warmer than 1986, consequently, foliar-applied XE-1019 reduced seed yields by an average of 23% and Parlay reduced seed yields by an average of 21%. Total dry weight and straw weight were unaffected by foliar-applied PGR treatment in both years.

Use of XE-1019 and Parlay in field crop production has the potential to reduce dry matter production and improve seed recovery, but results vary from year to year. These PGRs have the potential to improve seed yields and may be effective in improving harvest conditions by reducing vegetative biomass.

The Effects of Paclobutrazol and Uniconazol on Red Clover Seed Production

by

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THE EFFECTS OF PACLOBUTRAZOL AND UNICONAZOL ON RED CLOVER SEED PRODUCTION

INTRODUCTION

Red clover seed production. Red clover (*Trifolium pratense* L.) is the most important legume hay crop grown in the United States. About 7 million ha is planted to red clover and grass mixtures in North America (Taylor, 1985). Red clover seed is grown in many areas of the United States, with principal regions being the humid Midwest (50% of production) and Oregon (30 to 35% of production). In the Midwest, the hay crop is the most important crop with seed sometimes harvested as a secondary crop. In Oregon, the seed crop is the most important crop commodity harvested. Cropping practices differ in these two areas as a result of different climate and weather patterns. Warm, moist conditions in the Midwest are not as conducive to consistent high seed yields as the warm, dry conditions that exist in Oregon during the summer (Fergus and Holloway, 1960; Rincker and Rampton, 1985). Seed yields in Oregon are typically much higher than in the Midwest due to climatic advantages and management is primarily focused on the seed crop rather than the hay crop.

Red clover is the largest legume seed crop grown in Oregon. With 7000 to 8000 hectares planted annually and farmgate sales ranging from $5 to 8 million (Miles, 1992), red clover is an important part of Oregon's seed industry.

In Western Oregon, red clover is grown for seed under both irrigated and non-irrigated crop management systems. Excessive crop growth when adequate moisture is available during the red clover growing season can result in lodging. Lodging causes poor air circulation, resulting in conditions conducive to disease, flower abortion, plants rotting within the canopy (Oliva et al., 1994), and flowers to be less exposed for bee pollination. In addition, excessive crop biomass from prolific vegetative growth makes conditions during seed harvest more difficult and increases seed loss (Fergus and Holloway, 1960).

Reducing crop biomass with plant growth regulators (PGRs) could improve flowering and harvest conditions resulting in improved pollination, seed set, and seed recovery by optimizing an upright canopy structure and reducing vegetative growth (Rademacher, 1988). Another benefit of plant growth regulation may be the potential to shift assimilates from vegetative sinks to reproductive sinks (Lenton, 1984). Preliminary studies in Oregon and other red clover seed producing areas of the world have indicated potential benefits from the use of plant growth regulators on red clover grown for seed. In 1983, red clover seed yield in small plots within a commercial field in Oregon was increased by 54% with application of 0.15 kg ai/ha Parlay and plant height was decreased by 40% with application of 0.75 kg ai/ha Parlay. However, in the following year, no effect on seed yield and crop height was measured (Youngberg et al., 1984). In Finland, paclobutrazol applied at 1 l/ha increased tetraploid red clover seed yields by an average of 33% (Niemelainen, 1987). In Canada, research by Christie and Choo, (1990) reported red clover seed yields were increased by 80 kg/ha using Alar-85 in one trial, when grown with timothy (*Phleum pratense* L.), yet with similar trials they conducted during the same period, no seed yield response was measured.

Triazole plant growth regulators. Triazole compounds were first developed in the 1960's as fungicides. These compounds effectively interfere in fungal metabolisms by inhibiting sterol biosynthesis (Schulz and Scheinpflug, 1988). During the 1970's it was noticed that some triazoles screened for fungicidal activity also inhibited plant growth (Davis and Curry, 1991). As a result, in the early 1980's research also focused on plant growth regulating triazole compounds. Two of the most potent plant growth regulating triazoles compounds currently developed and available on the market are paclobutrazol ((2RS,3RS)-1-(4-chlorophenyl)- 4,4-dimethyl-2-(1,2,4-triazol-l-yl)pentan-3-ol) and uniconazol (E-1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl)penten-3-ol) (Lurssen, 1988).

Both paclobutrazol (trade names: PP333, Parlay, Bonzi) and uniconazol (trade names: XE-1019, S-3307, Sumagic) have fungicidal and plant growth regulating effects (Lurssen, 1987). Different enantiomers are specific for fungicidal or for growth regulating properties in these two compounds (Fletcher et al., 1986; Koller, 1987). Activity of uniconazol was shown to be higher and more persistent in the plant as a growth retardant than paclobutrazol (Steffens, 1988; Barnes et al., 1989). In addition to plant growth reduction, the fungicidal effect of these compounds may also be beneficial, indirectly enhancing the effectiveness of the PGR.

Significant height reduction by reduced internode growth is observed in triazole PGR treated plants. Research indicated that the major cause of plant growth regulation by triazoles PGRs results from inhibition of gibberellin biosynthesis. Triazole PGRs block the oxidation steps of ent-kaurene to ent-kaurenoic acid in the gibberellin biosynthesis pathway (Hedden and Graebe, 1985; Lurssen 1987). Reduction in gibberellin content was observed in triazole PGR treated plants (Rademacher et al., 1984). Growth inhibition by these compounds was prevented by adding gibberellins to treated plants (Dalziel and Lawrence, 1984; Lurssen, 1988; Fletcher and Hofstra, 1988) further substantiating the site of inhibitory activity.

Triazole PGRs are effective on a wide range of plants, work at very low concentrations (<10 mg/kg), are systemically active, and can be persistent in both plants and soil (Steffens, 1988). Paclobutrazol and uniconazol reduced stem elongation in beans (Fletcher, 1986; Sterrett, 1988), young apple trees (Steffens, 1988), corn and soybean (Barnes, et al., 1989) white clover (Fisher and Hayes, 1985) and other crops. Plants treated with triazole PGRs also showed effects not directly attributed to inhibition of gibberellin synthesis. Some of these effects were increases in specific leaf weight and root dry weight in young apple trees (Steffens, 1988), increased leaf chlorophyll content in bean *Phaseolus vulgaris* L., (Fletcher et al., 1986) and soybean, *Glycine max* L., (Barnes et al., 1989), increased root diameter in corn, *Zea mays* L. and soybean (Barnes et al 1989), increased root-to-shoot ratios (Rademacher, 1988), and reduced total water uptake and transpiration (Lurssen, 1987). These responses to triazoles are associated with other hormonal and physiological changes such as altered abscisic acid and cytokinin concentrations (Davis and Curry, 1991; Lurssen, 1988). On paclobutrazol-treated clover, nitrogen fixation by *Rhizobium trifolii* (Fisher and Hayes, 1985) was unaffected *in vitro*. Benefits from these effects include reduced pruning, earlier fruit bearing in apple, better root to shoot ratios for improved success of transplanted seedlings, smaller plant architecture without a loss in photosynthetic capabilities, and increased tolerance to drought stress.

Although paclobutrazol and uniconazol are very effective at inhibiting stem elongation in herbaceous and woody plants, there is little evidence of phytotoxicity to treated plants (Koller, 1987; Lurssen, 1987; Rademacher, 1988). This lack of phytotoxicity provides good crop safety in application. In addition to low phytotoxicity, these chemicals are not readily broken down in the plant resulting in longer systemic activity (Sterrett, 1988).

Plant uptake of paclobutrazol and uniconazol readily occurs through the root and stem regions with subsequent transport in the xylem along the transpiration stream (Fletcher et al., 1986; de Fraine and Worthington, 1986; Dalziel and Lawrence, 1984). Experiments also indicate good foliar uptake, but with little or no phloem mobility resulting in poor translocation (Stang and Weis, 1984; Wilfret, 1990). Soil application followed by irrigation or rainfall is recommended to move triazole PGRs to active uptake sites such as the root zone and the root-shoot interface in the plant (ICI Technical Information). Mixing in plant mediums or drenching are the most effective methods for PGR uptake in potted plants (Stang and Weis, 1984; Wilfret, 1990).

Soil persistence may be a problem if triazole sensitive crops are planted following harvest of treated crops (Niemelainen, 1987; Lurssen, 1988). This restriction would limit the use of paclobutrazol and uniconazol in field grown crop applications.

At the time of this research, uniconazol had not been used in trials involving red clover seed production and limited research results on the use of paclobutrazol in red clover seed production were available. Results from trials using these chemicals were inconsistent from year to year (Youngberg et al., 1984; Niemelainen, 1987; Christie and Choo, 1990).

This experiment was conducted to compare compound activity and measure the effects on crop growth and seed production with varying soil and foliar applied rates of paclobutrazol ((2RS,3RS)-1-(4-chlorophenyl)- 4,4-dimethyl-2-(1,2,4-triazol-l-yl)pentan-3-ol), trade name Parlay, and uniconazol, (E-1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl)penten-3-ol), trade name XE-1019. Also, to simulate irrigated and non-irrigated crop production practices common in the Willamette Valley, soil-applied PGR treatments were managed under either limited (single application) irrigation or multiple irrigation (three applications) during the growing season.

MANUSCRIPT I: THE EFFECTS OF SOIL-APPLIED PACLOBUTRAZOL AND UNICONAZOL ON RED CLOVER SEED PRODUCTION

ABSTRACT

Excessive growth by red clover, *Trifolium pratense* L., grown for seed interferes with maximum seed production and harvest in Oregon's Willamette Valley. This study was conducted during 1986 and 1987 on red clover cv. Kenland to determine whether plant height and dry matter production could be retarded and seed yields improved with the plant growth regulators (PGRs), uniconazol (XE-1019) and paclobutrazol (Parlay). The effects of different soil-applied PGRs and application rates on plant height, crop biomass, and yield components of red clover were measured at Corvallis, OR on Woodburn silt-loam (fine-silty mixed mesic Aquultic Argixerolls) soil. PGR applications were also managed under single and multiple irrigation regimes in 1986.

In 1986, under a single irrigation regime, XE-1019 applied at 1.12 kg ai/ha reduced canopy height by 32% and Parlay applied at 1.68 kg ai/ha reduced height by 13%. Over the two-year period, straw yield was reduced by 40% with XE-1019 (1.12 kg ai/ha) and by 12% with Parlay (1.68 kg ai/ha). Seed yield was increased by 11% with lower XE-1019 rate (0.14 kg ai/ha) and was increased by 14% with higher Parlay rate (1.68 kg ai/ha). PGR treatments under multiple irrigation reduced canopy height by 25% with XE-1019 (1.12 kg ai/ha) and by 11% with Parlay (1.68 kg ai/ha). Straw yield was reduced by 30% with XE-1019 (0.84 kg ai/ha), but Parlay had no effect on straw yield. In addition, seed yield was increased by 8% with XE-1019 (0.56 kg ai/ha) and by 18% with Parlay (1.68 kg ai/ha).

Use of XE-1019 and Parlay in field crop production has the potential to reduce dry matter production and improve seed recovery, but results vary from year to year. These PGRs have the potential to improve seed yields and may be effective at improving harvest conditions by reducing vegetative biomass.

INTRODUCTION

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Reducing crop biomass with plant growth regulators (PGRs) could improve flowering and harvest conditions resulting in improved pollination, seed set, and seed recovery by optimizing an upright canopy structure and reducing excessive vegetative growth (Rademacher, 1988). Another benefit of plant growth regulation may be the shifting of assimilate partitioning from vegetative sinks to reproductive sinks (Lenton, 1984). Preliminary studies in Oregon and other seed red clover producing areas of the world have indicated potential benefits from the use of plant growth regulators on red clover grown for seed. In 1983, red clover seed yield in small plots within a commercial field in Oregon was increased by 54% with application of 0.15 kg ai/ha Parlay and plant height was decreased by 40% with application of 0.75 kg ai/ha Parlay, however, in the following year, no effect on seed yield and crop height was measured. (Youngberg et al., 1984). In Finland, paclobutrazol applied at 1 l/ha increased tetraploid red clover seed yields by an average of 33% (Niemelainen, 1987). In

Canada, research by Christie and Choo, (1990) reported red clover seed yields were increased by 80 kg/ha using Alar-85 in one trial, when grown with timothy (*Phleum pratense* L.), yet with similar trials they conducted during the same period, no seed yield response was measured.

This experiment was conducted to measure the effects on crop growth and seed production with varying rates of two soil-applied triazole-type PGRs, paclobutrazol ((2RS,3RS)-1-(4-chlorophenyl)- 4,4-dimethyl-2-(1,2,4-triazol-l-yl)pentan-3-ol), trade name Parlay, and uniconazol, (E-1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl)penten-3-ol), trade name XE-1019. In addition to application of the PGRs, red clover seed production management was evaluated under single and multiple irrigation (three applications) regimes similar to cropping practices in Oregon's Willamette Valley.

MATERIALS AND METHODS

Research was conducted at Oregon State University's Hyslop Crop Science Field Research Laboratory, Corvallis, Oregon. The soil is classified as Woodburn silt-loam (fine-silty mixed mesic Aquultic Argixerolls).

Red clover cv. Kenland was planted September 1984 for the 1986 experiments, and September 1986 for the 1987 experiments using a Nordsten drill set at 30 cm row spacing and 7.8 kg/ha seeding rate. Crop stands were managed for fertility and weed control according to standard cultural practices used in Oregon's Willamette Valley. The 1984 stand was flail chopped and removed in May 1985 for a hay cutting and again in August 1985 to simulate seed crop removal.

Experimental plots were marked out in the established red clover stands following hay removal June 3, for 1986 experiments and May 22, for 1987 experiments. In addition to providing a hay crop, removal of spring growth helps control the clover seed midge, *Dasineura leguminicola* (Lintner), and to synchronize crop regrowth for uniform bloom and seed maturation (Dade, 1966; Kamm, 1984) during warm and dry conditions in the summer for better seed crop production (Fergus and Holloway, 1960).

PGR treatments were applied to 1.8 m by 6.1 m plots using a CP-15 backpack sprayer at the initiation of crop regrowth (10 d after hay cutting). The backpack sprayer was equipped with a 1.5 m wide hand-held boom with six 8002 TeeJet nozzles at 30-cm intervals. Treatments were as follows: XE-1019 in a 50% wettable powder applied at 0.14, 0.28, 0.56, 0.84, and 1.12 kg active ingredient per hectare (kg ai/ha); Parlay in a 50% wettable powder applied at 0.28, 0.56, 1.12, and 1.68 kg ai/ha; and one untreated check plot. In 1987, two treatments (XE-1019 at 1.68 kg ai/ha and Parlay at 2.24 kg ai/ha) were added. Irrigation (50 mm was applied following PGR applications to move the chemical into the active root zone of the plants (ICI Technical

Information) and to provide additional moisture for regrowth. Experimental design was a randomized complete block with six replications of ten treatments in 1986 and 12 treatments in 1987.

In 1986, in addition to the PGR treatments, the red clover was managed under two sprinkler irrigation regimes. Both experiments received a single 50 mm irrigation application following the PGR applications, and the second experiment received two more 50 mm irrigation applications; one at canopy closure (July 7) and one during bloom (August 4). In 1987, only a single irrigation regime was used on the PGR treatments. The two irrigation studies were conducted in separate red clover stands far enough apart to allow irrigation treatments on one experiment and not the other.

There was not enough crop planted in 1986 to provide area for both single and multiple irrigation applications, so no multiple irrigation regime experiment was conducted in 1987.

To quantify plant growth rates, canopy height measurements were taken *in situ* during the growing season. Inflorescence and stem number at maturity were obtained by removing one 30-cm section of row from each plot. Ten inflorescences were randomly selected from each plot to determine calyx number per inflorescence. Potential seed number (per unit area) was calculated from the measured yield components. Actual seed number was calculated by dividing harvested seed yield per plot by mean seed weight. Samples were also taken from XE-1019-treated plots (0.14 and 1.12 kg ai/ha in 1986, and 0.14 and 1.68 kg ai/ha in 1987), Parlay-treated plots (1.12 kg ai/ha), and the untreated check to measure the effect of PGRs on stem internode length and number.

Plots were harvested at seed maturity during the last week of August into burlap sacks using a small plot harvester with a sickle bar cutter and draper designed to efficiently harvest the entire above-ground biomass. Harvested plots were air-dried, threshed using a belt thresher, and seed was cleaned using an M2-B air-screen seed cleaner. Two-year analysis for the soil-applied PGRs under single irrigation was conducted using a split-block design with year as the whole plot factor and PGR treatment as the subplot factor. Statistical analysis was done using MSUSTAT statistical analysis software (Lund, 1988).

RESULTS

Soil-applied PGRs under single irrigation management, 1986 and 1987. XE-1019 reduced canopy height by 32% in 1986. With higher rates resulting in lower canopy height (Table I-1). In 1987, XE-1019 reduced canopy height early during regrowth of the crop (Table I-2), but by harvest no height differences were evident. Parlay also reduced canopy height in 1986 similar to XE-1019, though the reduction in height was less (13%) compared to XE-1019 at the same rate. Other research has also shown greater plant height reduction of XE-1019 over Parlay (Steffens, 1988; Barnes et al., 1989). In 1987, the only height reduction from Parlay occurred early during regrowth (July 2) and only at the highest PGR rate (2.24 kg ai/ha).

Canopy height was reduced early during regrowth with PGR-treated plants, but by the end of the growing season prior to harvest in 1986, PGR-treated plants seemed to regrow faster than the untreated check indicating a reduction in the activity of the PGRs. Plants in the check plots completed most of their growth by early to mid-July; however, treated plants showed continued growth between the last two measurement dates, July 17 to August 25 (Table I-1).

Reduction in height during 1986 resulted from shorter mean internode lengths as shown in Table I-3. The bottom three to four internodes (Table I-4) were the main contributors to height reduction, indicating inhibition of early regrowth. The highest rate of XE-1019 (1.12 kg ai/ha) reduced in length all but the uppermost internode. Mean internode number per stem was unaffected by PGR treatments. Reductions of internode length by inhibition of gibberellin synthesis is consistent with other research findings (Hedden and Graebe, 1985; Lurssen 1987).

Early season regrowth was reduced by both growth regulators. By mid-season, (July 9-17), only XE-1019 treated plants exhibited less regrowth in contrast to Parlay treatments, which were now growing at the same rate as the untreated check. Research by Steffens (1988) also reported greater persistence of XE-1019 than Parlay.

Although *in situ* canopy height at harvest was not significantly reduced by PGR treatments in 1987, the higher rate of XE-1019 (1.68 kg ai/ha) reduced average stem length by 24% (Table I-5). This reduction in stem length was caused by both fewer internodes and shorter mean internode lengths (though not statistically different) (Table I-5), whereas only shorter internode lengths were observed in 1986. Mean internode length was not reduced, nor were individual internode lengths (Table I-6). Lack of overall crop regrowth in 1987 was a result of warmer and dryer than normal weather conditions throughout the growing season. Five of the six growing season months (March - August) had less than normal precipitation, higher than normal temperatures, and had high levels of pan evaporation (Appendix 1).

Increased rates of XE-1019 and Parlay reduced total dry weight by 37% with XE-1019 and by 10% with Parlay. Straw yield at harvest was reduced by 40% with XE-1019 and by 12% with Parlay (Table I-7). XE-1019 reduced total and straw dry weight more than Parlay at comparable rates. Seed yield responded differently to XE-1019 to Parlay; the lowest rate of XE-1019 increased seed yield by 11%, whereas the highest rate of Parlay increased seed yield by 14% over the untreated check. General trends indicate improved seed yield with lower rates of XE-1019 or higher rates of Parlay. The reasons for these responses are unclear in this study.

Harvest index (the ratio of seed yield to total dry weight) was increased by 40% with XE-1019 and by 24% with Parlay. A decrease in dry matter caused by XE-1019 reduced both straw yield and seed yield with the greater effect on straw yield, hence the increased harvest index. With Parlay, straw yield was slightly reduced yet seed production showed improvement, especially at the highest rate (1.68 kg ai/ha). Overall, both PGRs improved harvest index (though with different harvest components affected), an important measure of plant efficiency in seed production, indicating a shift of assimilate partitioning from vegetative to reproductive processes.

Due to the difference in weather conditions between 1986 and 1987, total dry weight, straw yield, seed yield, harvest index were greatly reduced in 1987 compared to 1986 (Table I-8). Seed weight remained constant across years.

Inflorescence number and potential seed yield estimates were not adversely affected by PGR treatment. Other yield component variables measured (stem number, heads per stem, and calyxes per head) were similarly unaffected by PGR treatments in 1986 (Table I-9).

Soil-applied PGRs under full irrigation management, 1986. Canopy height was reduced with XE-1019 and Parlay treatments (Table I-10). Higher rates of XE-1019 continued to reduce canopy height up to 25%; by comparison, Parlay rates above 0.68 kg ai/ha reduced height by only 11%. All PGR treatments except the lowest Parlay rate (0.28 kg/ha) reduced canopy height during the first three measurement dates. By the last measurement date (harvest), the only treatments shorter than the untreated check, were the two highest rates of XE-1019 (0.84 and 1.12 kg ai/ha) and the highest rate of Parlay (1.68 kg ai/ha). Response of treated plants to lower rates of XE-1019 than to Parlay has been observed in previous studies (Steffens, 1988; Barnes et al., 1989). In this study, about 1/2 to 1/4 of the rate of XE-1019 was needed to give equivalent responses in growth retardation that was measured with Parlay. Regrowth difference prior to harvest (July 17-August 25) tended to increase as XE-1019 treatments increased ($p < 0.1$).

Mean stem length and mean internode length were reduced by the higher rate (1.12 kg ai/ha) of XE-1019 and Parlay (Table I-11). When Parlay was applied at the same rate as XE-1019 the height reduction was intermediate to the highest and lowest rate of XE-1019. Mean internode number was unaffected by PGR treatments. The highest rate of XE-1019 shortened four of the six internodes, whereas the same rate of Parlay only shortened internode number 5 (Table I-12).

Harvest dry weight was reduced by 26% and straw yield was reduced by 30% with XE-1019 treatments. Parlay treatments had no effect on total dry weight or straw yield. Seed yield was increased by 19% with the higher Parlay treatments (Table I-13), whereas seed yield was unaffected by XE-1019. Harvest index increased up to 26% with XE-1019 and up to 15% with Parlay, similar to that found under single irrigation though somewhat less in magnitude (Table I-7). PGR treatments had no effect on seed weight. No other yield components (stem number, heads per stem, flowers per head) were affected by the PGR treatments (Table I-14).

DISCUSSION

A lower rate of XE-1019 (0.14 kg ai/ha) and a higher rate of Parlay (1.68 kg ai/ha) were used to make comparisons of activity since it was reported that XE-1019 affected plant growth at much lower rates than Parlay (Steffens, 1988; Barnes et al., 1989). Results from this study confirm that XE-1019 is more effective at reducing plant height and dry matter production.

Although XE-1019 was more effective in reducing plant height and dry matter than Parlay, plant responses to Parlay and XE-1019 were not similar. Plant height increased with increasing rate of XE-1019, but response to Parlay did not increase beyond moderate rates with the highest rate of 1.68 kg ai/ha showing not much different response than the moderate rate of 0.56 kg ai/ha. The lack of response to higher rates of paclobutrazol is consistent with results of preliminary research showing little change in height with Parlay rates greater than 0.20 kg/ha (Youngberg et al., 1984). It is apparent the activity of PGRs decreased during growth and had less activity on top internode growth.

Parlay had less effect on straw yield than XE-1019 (Table I-7) and seed yield response was very different: increased rates of XE-1019 reduced seed yield, whereas increased rate of Parlay improved seed yield. These responses were observed in both single irrigation and multiple irrigation regimes.

Even though harvest index increased with higher rates of XE-1019 in 1987, (Table I-7), the resultant reduction in seed yield may have been caused by less stem and leaf area available for photosynthetic activity. The detrimental economical effect of reduced income far outweighs the beneficial reduction in dry matter which may have allowed for more efficient harvest.

XE-1019 and Parlay had greater relative effects in decreasing dry weight, plant height and straw yield, and increasing harvest index, with a single irrigation rather than with multiple irrigation. However, Parlay improved yields with multiple irrigation more than with single a irrigation.

Soil-applied PGRs can effectively reduce canopy height and total dry matter in red clover without decreasing seed yield. Parlay increased seed yield under multiple irrigation which may point to improved seed production using PGRs with higher levels of inputs such as multiple irrigation. Without additional irrigation, both PGRs improved yields over the two-year study even with reductions in total dry matter production, resulting in an improved harvest index. In drought conditions, such as in 1987, the use of PGRs was detrimental because dry matter reductions were too great and in turn, reduced yields. Additional research would be required to better understand the total impact of Parlay and XE-1019 on plant growth, development, and seed yield production.

It is unclear how seed yields were improved by PGR treatment as no plant components of yield were affected. It is possible that improved seed set and seed recovery resulted from PGR treatment. These factors should be examined in further studies.

Table I-1. Canopy height of red clover seed crops treated with soil-applied PGRs under single irrigation, 1986.

Treatment rate	Sampling date: June 30	Sampling date: July 9	Sampling date: July 17	Sampling date: August 25	Height change: June 30-July 9	Height change: July 9-July 17	Height change: July 17-August 25
kg ai/ha	cm						
Check	29.8	45.3	49.8	55.3	15.5	4.5	5.5
XE-1019							
0.14	24.9	40.9	45.8	54.0	16.0	4.8	8.3
0.28	21.5	37.1	40.9	49.3	15.6	3.8	8.3
0.56	19.8	33.2	37.0	47.6	13.4	3.8	10.6
0.84	18.6	30.3	33.2	42.6	11.8	2.8	9.4
1.12	18.1	28.0	29.0	37.8	9.9	1.0	8.8
Parlay							
0.28	25.1	41.4	45.8	53.3	16.3	4.4	7.5
0.56	23.9	40.3	43.3	50.3	16.3	3.0	6.9
1.12	21.3	37.5	40.8	48.2	16.2	3.3	7.4
1.68	20.9	35.5	38.8	48.9	14.6	3.3	10.2
LSD 0.05	1.8	2.9	3.0	3.5	2.7	NS	NS
P-value	<0.001	<0.001	<0.001	<0.001	<0.001		
Mean	22.4	37.0	40.4	48.7	14.6	3.5	8.3

Table I-2. Canopy height of red clover seed crops treated with soil-applied PGRs under single irrigation, 1987.

	Sampling date				Height change		
Treatment rate	July 2	July 10	August 7	August 28	July 2-July 10	July 10-August 7	August 7-August 28
kg ai/ha	cm						
Check	25.2	25.1	36.8	37.3	-0.1	11.7	0.6
XE-1019							
0.14	23.5	24.3	34.8	37.5	0.8	10.5	2.8
0.28	21.4	23.0	32.3	33.4	1.6	9.3	1.2
0.56	18.9	19.0	29.9	34.5	0.1	10.9	4.6
0.84	19.3	19.9	30.3	36.7	0.7	10.3	6.4
1.12	17.8	18.6	28.3	29.7	0.8	9.7	1.4
1.68	17.2	18.3	27.5	32.2	1.2	9.2	4.8
Parlay							
0.28	23.7	22.8	34.2	36.4	-0.9	11.4	2.3
0.56	21.7	24.1	32.8	36.2	2.4	8.8	3.3
1.12	22.1	22.7	34.8	33.8	0.6	12.2	-1.1
1.68	22.2	23.2	33.0	35.5	1.0	9.8	2.5
2.24	21.6	23.9	32.8	35.4	2.3	8.8	2.4
LSD 0.05	3.5	3.3	5.2	NS	NS	NS	NS
P-value	<0.001	<0.001	0.017				
Mean	21.2	22.1	32.2	34.9	0.9	10.2	2.6

Table I-3. Reproductive stem measurements in red clover seed crops treated with soil-applied PGRs under single irrigation, 1986.

Treatment rate	Stem length	Mean internode length	Internode
kg ai/ha	------------------ cm	---------------	no.
Check	51.1	9.0	5.7
XE-1019			
0.14	49.2	8.3	6.0
1.12	38.5	6.4	6.1
Parlay			
1.12	44.2	8.2	5.5
LSD 0.05	5.4	0.7	NS
P-value	0.001	<0.001	
Mean	45.8	7.9	5.8

Table I-4. Reproductive stem internode lengths in red clover seed crops treated with soil-applied PGRs under single irrigation, 1986.

Treatment	Internode					
rate	Top	2	3	4	5	6
kg ai/ha	----	----	----	cm ----	----	----
Check	4.2	8.6	11.6	12.3	10.7	7.0
XE-1019						
0.14	3.9	7.9	11.0	12.1	9.5	6.6
1.12	3.9	7.2	9.0	8.6	6.7	3.9
Parlay						
1.12	4.3	9.2	11.7	11.0	7.6	3.9
LSD 0.05	NS	1.1	1.4	1.7	1.5	2.1
P-value		0.007	0.003	0.001	<0.001	0.008
Mean	4.1	8.2	10.8	11.0	8.6	5.3

Table I-5. Reproductive stem measurements in red clover seed crops treated with soil applied PGRs under single irrigation, 1987.

Treatment rate	Stem length	Mean internode length	Internode
kg ai/ha	----------------- cm	-----------------	no.
Check	28.1	4.9	5.8
XE-1019			
0.14	26.5	4.7	5.8
1.68	21.6	4.2	5.2
Parlay			
1.12	26.3	4.3	6.2
LSD 0.05	4.4	NS	0.6
P-value	.036		.016
Mean	25.6	4.5	5.7

Table I-6. Reproductive stem internode lengths in red clover seed crops treated with soil-applied PGRs under single irrigation, 1987.

Treatment	Internode					
rate	Top	2	3	4	5	6
kg ai/ha	cm					
Check	1.5	4.4	6.4	6.8	6.3	4.8
XE-1019						
0.14	1.5	4.0	5.7	6.4	5.7	5.4
1.68	1.5	3.8	5.6	5.7	4.3	4.0
Parlay						
1.12	1.0	3.2	5.4	6.3	5.9	3.9
LSD 0.05	NS	NS	NS	NS	NS	NS
P-value						
Mean	1.4	3.9	5.8	6.3	5.5	4.5

Table I-7. Total dry weight, straw yield, seed yield, harvest index, and seed weight means for soil applied PGR treatments in red clover seed crops under single irrigation averaged across 1986 and 1987.

Treatment rate	Total dry weight	Straw yield	Seed yield	Harvest index	Seed weight
	---------- kg/ha	----------	----------	%	mg
Check	4002	3595	407	8.9	1.60
XE-1019					
0.14	4064	3610	455	9.6	1.62
0.28	3470	3039	431	10.8	1.62
0.56	3283	2845	437	11.3	1.62
0.84	3052	2620	431	12.3	1.61
1.12	2542	2165	378	12.6	1.59
Parlay					
0.28	3777	3367	411	9.4	1.61
0.56	3672	3234	438	10.5	1.60
1.12	3570	3131	440	10.5	1.61
1.68	3638	3172	466	11.1	1.60
LSD 0.05	361	335	46	1.0	NS
P-value	<0.001	<0.001	.0214	<0.001	
Mean	3506	3078	429	10.7	1.61

Table I-8. Total dry weight, straw yield, seed yield, harvest index, and seed weight means in red clover seed crops under single irrigation averaged across soil-applied PGR treatments.

Year	Total dry weight	Straw yield	Seed yield	Harvest index	Seed weight
	------------------- kg/ha	-------------------	-------------------	%	mg
1986	5253	4517	736	14.1	1.61
1987	1761	1639	123	7.3	1.61
LSD 0.05	1071	930	148	0.9	NS
P-value	<0.001	<0.001	<0.001	<0.001	
Mean	3506	3078	429	10.7	1.61

Table I-9. Yield components in red clover seed crops treated with soil-applied PGRs under single irrigation, 1986.

Treatment rate	Inflore-scences	Fertile stems	Inflorescenses per stem	Calyx per head	Seed number Potential	Seed number Actual	Floret site utili-zation
kg ai/ha	----- no./30 cm ------		------- no. -------		-- no. X $10^3/m^2$ --		%
Check	102	33	3.2	111	67.7	24.3	41
XE-1019							
0.14	93	32	2.8	110	62.8	26.3	55
0.28	111	36	2.9	108	71.0	25.1	46
0.56	112	33	3.2	114	74.6	26.2	37
0.84	86	29	3.0	120	60.9	25.2	44
1.12	103	35	3.0	107	66.6	23.1	38
Parlay							
0.28	101	31	3.4	112	67.4	23.9	37
0.56	95	33	2.8	112	63.7	25.9	44
1.12	126	32	4.0	116	86.7	26.5	34
1.68	128	39	3.3	111	85	27	36
LSD 0.05							
P-value	NS	NS	NS	NS	NS	NS	NS
Mean	106	33	3.2	112	70.6	25.3	41

Table I-10. Canopy height of red clover seed crops treated with soil-applied PGRs under multiple irrigations, 1986.

Treatment rate	Sampling date: June 30	July 9	July 17	August 25	Height change: June 30-July 9	July 9-July 17	July 17-August 25
kg ai/ha	cm						
Check	32.6	47.5	52.9	56.2	14.9	5.4	3.3
XE-1019							
0.14	27.3	38.7	44.0	53.2	11.4	5.3	9.2
0.28	26.2	38.4	44.3	52.0	12.3	5.8	7.8
0.56	24.2	34.3	38.4	51.3	10.2	4.1	12.9
0.84	22.8	30.0	33.5	44.0	7.3	3.5	10.5
1.12	22.6	31.5	32.1	42.2	8.9	0.6	10.0
Parlay							
0.28	31.0	43.2	49.0	56.7	12.2	5.8	7.7
0.56	26.9	41.4	45.8	53.2	14.5	4.3	7.4
1.12	26.7	38.4	42.3	53.2	11.8	3.8	10.9
1.68	26.6	37.5	42.8	50.2	10.9	5.3	7.4
LSD 0.05	3.4	2.4	4.2	5.1	3.2	NS	NS
P-value	<0.001	<0.001	<0.001	<0.001	<0.001		
Mean	26.7	38.1	42.5	51.2	11.4	4.4	8.7

Table I-11. Reproductive stem measurements in red clover seed crops treated with soil-applied PGRs under multiple irrigations, 1986.

Treatment rate	Stem length	Mean internode length	Internode
kg ai/ha	---------------- cm	----------------	no.
Check	61.0	9.8	6.3
XE-1019			
0.14	52.6	9.0	5.9
1.12	42.2	7.1	6.1
Parlay			
1.12	50.8	8.7	6.0
LSD 0.05	8.7	1.1	NS
P-value	0.003	0.001	
Mean	51.6	8.7	6.1

Table I-12. Reproductive stem internode lengths in red clover seed crops treated with soil-applied PGRs under multiple irrigations, 1986.

Treatment	Internode					
rate	Top	2	3	4	5	6
kg ai/ha	cm					
Check	4.9	10.0	13.2	13.1	11.3	7.1
XE-1019						
0.14	6.3	10.7	12.2	11.8	8.9	5.8
1.12	4.5	8.2	10.5	9.5	6.6	4.2
Parlay						
1.12	4.3	9.0	11.7	12.0	9.2	6.7
LSD 0.05	1.0	1.4	1.5	1.6	1.9	NS
P-value	0.004	0.008	0.014	0.002	0.001	
Mean	5.0	9.5	11.9	11.6	9.0	5.9

Table I-13. Total dry weight, straw yield, seed yield, harvest index, and seed weight in red clover seed crops treated with soil-applied PGRs under multiple irrigations, 1986.

Treatment rate	Plot dry weight	Straw yield	Seed yield	Harvest index	Seed weight
kg ai/ha	----------------------	kg/ha	----------------------	%	mg
Check	6202	5355	848	13.7	1.65
XE-1019					
0.14	5461	4690	780	13.9	1.66
0.28	5950	5107	844	14.3	1.67
0.56	5530	4617	914	16.6	1.68
0.84	4617	3793	816	17.3	1.63
1.12	5240	4357	882	16.8	1.68
Parlay					
0.28	6581	5645	938	14.2	1.69
0.56	6235	5297	938	15.0	1.64
1.12	6163	5191	974	15.8	1.65
1.68	6434	5428	1006	15.6	1.64
LSD 0.05	646	554	122	1.4	0.05
P-value	<0.001	<0.001	0.009	<0.001	.008
Mean	5842	4948	894	15.3	1.66

Table I-14. Yield components in red clover seed crops treated with soil-applied PGRs under multiple irrigations, 1986.

Treatment rate	Inflore-scences	Fertile stems	Inflore-scence per stem	Calyx per head	Seed number Potential	Seed number Actual	Floret site utili-zation
kg ai/ha	no./30 cm	no./30 cm	no.	no.	no. X $10^3/m^2$	no. X $10^3/m^2$	%
Check	94	30	3.2	123	69.3	28.6	44
XE-1019							
0.14	122	41	2.9	115	83.4	26.0	36
0.28	118	38	3.1	124	87.6	28.1	35
0.56	110	34	3.3	118	78.4	30.1	48
0.84	104	33	3.2	114	71.0	27.8	42
1.12	110	30	3.6	114	73.9	29.2	42
Parlay							
0.28	120	36	3.2	122	86.0	30.7	44
0.56	113	32	3.3	115	76.6	31.7	58
1.12	117	34	3.5	116	82.5	32.9	43
1.68	117	29	4.0	114	80.5	34	54
LSD 0.05	NS	NS	NS	NS	NS	3.7	NS
P-value						0.002	
Mean	112	34	3.3	117	78.9	29.9	45

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MANUSCRIPT II: THE EFFECTS OF FOLIAR-APPLIED PACLOBUTRAZOL AND UNICONAZOL ON RED CLOVER SEED PRODUCTION.

ABSTRACT

Excessive growth by red clover, *Trifolium pratense* L., grown for seed interferes with maximum seed production and harvest in Oregon's Willamette Valley. This study was conducted during 1986 and 1987 on red clover cv. Kenland to determine whether plant height and dry matter production could be inhibited and seed yields improved with the plant growth regulators (PGRs), uniconazol (XE-1019) and paclobutrazol (Parlay). The effects of different foliar-applied PGRs and application rates on plant height, crop biomass, and yield components of red clover were measured at Corvallis, OR on Woodburn silt-loam (fine-silty mixed mesic Aquultic Argixerolls) soil.

XE-1019 (1.12 kg ai/ha) reduced canopy height by 13% in 1986 and by 25% in 1987, whereas Parlay (1.12 kg ai/ha) reduced canopy height by 9% in 1986 and by 19% in 1987. In 1986, seed yield increases averaged 16% across all XE-1019 treatments (0.07 to 1.12 kg ai/ha) and yield was increased an average of 21% across all Parlay treatments (0.28 to 1.68 kg ai/ha). However, in 1987, XE-1019 reduced seed yields by 23% and Parlay reduced seed yields by 21%. Warmer and drier conditions in 1987 than in 1986 contributed to overall yield reductions. Total dry weight and straw weight were unaffected by PGR treatments in both years.

Although XE-1019 and Parlay did not reduce vegetative biomass, these PGRs have good potential to improve seed yields. Since PGR effects were not consistent between years, the reason for these differences needs to be examined in future studies.

INTRODUCTION

Red clover is the largest legume seed crop grown in Oregon. With 7000 to 8000 hectares planted annually and farmgate sales ranging from $5 to 8 million (Miles, 1992), red clover is an important part of Oregon's seed industry.

In Western Oregon, red clover is grown for seed under both irrigated and non-irrigated crop management systems. Excessive crop growth when adequate moisture is available during the red clover growing season can result in lodging. Lodging causes poor air circulation, resulting in conditions conducive to disease, flower abortion, plants rotting within the canopy (Oliva et al., 1994), and flowers to be less exposed for bee pollination. In addition, excessive crop biomass from prolific vegetative growth makes conditions during seed harvest more difficult and increases seed loss (Fergus and Holloway, 1960).

Reducing vegetation volume with plant growth regulators (PGRs) could improve flowering and harvest conditions resulting in improved pollination, seed set, and seed recovery by optimizing an upright canopy structure and reducing excessive vegetative growth (Rademacher, 1988). Another benefit of plant growth regulation may be the shifting of assimilate partitioning from vegetative sinks to reproductive sinks (Lenton, 1984). Preliminary studies in Oregon and other seed red clover producing areas of the world have indicated potential benefits from the use of plant growth regulators on red clover grown for seed. In 1983, red clover seed yield in small plots within a commercial field in Oregon was increased by 54% with application of 0.15 kg ai/ha Parlay and plant height was decreased by 40% with application of 0.75 kg ai/ha Parlay, however, in the following year, no effect on seed yield and crop height was measured. (Youngberg et al., 1984). In Finland, paclobutrazol applied at 1 l/ha increased tetraploid red clover seed yields by an average of 33% during 1985-86 (Niemelainen, 1987). In Canada, research by Christie and Choo, (1990) reported red clover seed yields were increased by 80 kg/ha using Alar-85 in one trial, when grown with timothy (*Phleum pratense* L.), yet with similar trials they conducted during the same periond, no seed yield response was measured.

Some success with foliar application of paclobutrazol and uniconazol was shown with potted chrysanthemums (Wilfret, 1990). Use of foliar-applied PGRs would allow application at any time in crop growth and not require irrigation to move the chemical into the root zone for uptake. Research by Niemelainen (1987) with paclobutrazol treatments applied at bloom resulted in seed yield increases.

This experiment was conducted to measure the effects on crop growth and seed production of varying foliar-applied rates applied during canopy regrowth of two triazole type PGRs, paclobutrazol ((2RS,3RS)-1-(4-chlorophenyl)- 4,4-dimethyl-2-(1,2,4-triazol-l-yl)pentan-3-ol), trade name Parlay, and uniconazol, (E-1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl)penten-3-ol), trade name XE-1019 on seed production.

MATERIALS AND METHODS

Research was conducted at Oregon State University's Hyslop Crop Science Field Research Laboratory, Corvallis, Oregon. The soil is classified as Woodburn silt-loam (fine-silty mixed mesic Aquultic Argixerolls).

Red clover cv. Kenland was planted September 1984 for the 1986 experiment, and September 1986 for the 1987 experiments using a Nordsten drill set at 30 cm row spacing and 7.8 kg/ha seeding rate. Crop stands were managed for fertility and weed control according to standard cultural practices in use in Oregon's Willamette Valley. The 1984 stand was flail chopped and removed in May 1985 for a hay cutting and again in August 1985 to simulate a seed crop removal (Fergus and Holloway).

Experimental plots were placed in the established red clover stands following hay removal on June 3, for 1986 experiments and May 22, for 1987 experiments. In addition to providing a hay crop, removal of spring growth helps control the clover seed midge, *Dasineura leguminicola* (Lintner), and synchronize crop regrowth for uniform bloom and seed maturation (Dade, 1966; Kamm, 1984) during warm and dry conditions in the summer for better seed crop production.

Foliar-applied PGR treatments were applied to 1.8 m by 6.1 m plots using a CP-15 backpack sprayer. The backpack sprayer was equipped with a 1.5m wide hand-held boom with six 8002 TeeJet nozzles at 30 cm intervals. Treatments for 1986 were applied at canopy closure on June 26, 1986 as follows: XE-1019 in an emulsifiable concentrate formulation (0.12 kg ai/l) applied at 0.07, 0.14, 0.28, 0.56, and 1.12 kg active ingredient per hectare (ai/ha) and Parlay 50% wettable powder (mixed with a spreader-sticker) at 0.28, 0.56, 1.12, and 1.68 kg ai/ha; and one untreated check plot. Treatments for 1987 were as follows: three rates (0.28, 0.56, 1.12 kg ai/ha) of Parlay and XE-1019 applied at two different times of canopy regrowth: canopy closure (June 17, 1987) and prebloom (July 10, 1987). The experimental design was a randomized complete block with ten treatments replicated in six blocks in 1986 and 13 treatments replicated in four blocks in 1987.

To quantify plant growth rate, canopy height measurements were taken *in situ* during the growing season. Inflorescence and stem number at maturity were obtained by removing one 30-cm section of row from each plot. Ten inflorescences were randomly selected from each plot to determine calyx number per inflorescence. Potential seed number (per unit area) was calculated from yield components measured. Actual seed number was calculated by dividing harvested seed yield per plot by mean (thousand) seed weight. Samples were also taken from XE-1019-treated plots (0.14 and 1.12 kg ai/ha), Parlay-treated plots (1.12 kg ai/ha), and the untreated check in 1986, and from XE-1019- and Parlay-treated plots (1.12 kg ai/ha) to measure the specific growth effect on stem internode lengths and number. Samples were taken in plots treated at both canopy closure and prebloom growth stages.

Plots were harvested at seed maturity during the last week of August into burlap sacks using a small plot harvester with a sickle bar cutter and draper designed to efficiently harvest the entire above-ground biomass. Harvested plots were air-dried, threshed using a belt thresher, and seed was cleaned using an M2-B air-screen seed cleaner. Statistical analysis was done using MSUSTAT statistical analysis software (Lund, 1988).

RESULTS

Foliar-applied PGRs, 1986. Canopy regrowth in 1986 was retarded following June 26 foliar applications of XE-1019 and Parlay (Table II-1). The reduced change in height for June 30 - July 9 period was greatest with 0.56 kg ai/ha XE-1019 treatment (5.4 cm less than the check treatment) and the 1.12 kg ai/ha Parlay treatment (2.9 cm less than the check treatment). By July 17 all PGR treated plots were reduced in height compared to the check treatment. During the period from July 9 to July 17, the highest rate of Parlay (1.68 kg ai/ha) and all XE-1019 treatment rates greater than 0.14 kg ai/ha inhibited growth. At harvest (August 25), XE-1019 rates showed a trend toward reduced height ($p < 0.10$). Parlay treatments were not as effective as XE-1019 in reducing height throughout the growing season, yet all PGR treatments were shorter than the untreated check on August 25.

Mean stem and internode length were both reduced by XE-1019 (Table II-2). Parlay reduced stem length and internode number, but not mean internode length. Internode growth inhibition occurred between elongation of the fifth and second nodes (Table II-3).

Foliar-applied PGRs had no effect on total dry matter or straw (straw yield = total dry weight - seed yield) production (Table II-4). However, seed yield and harvest index in 1986 were improved by applications of XE-1019 and Parlay. Seed weight was reduced by the highest rate of XE-1019, but there is no apparent reason for this reduction. Seed yield was increased as a result of more inflorescences per stem (Table II-5). No other components of yield were affected by PGR treatments.

Foliar applied PGRs, 1987. Five of the six growing season months (March - August) in 1987 had substantially less than normal precipitation, higher than normal temperatures, and high levels of pan evaporation at the experiment site (Appendix 1).

Unusually warm and dry weather throughout the growing season was a major cause for lack of regrowth and poor seed yields in 1987. Bloom started three weeks earlier than in 1987 and slowly progressed as the crop matured. Therefore, the results in 1987 may reflect the situation in years such as 1986 that experience more normal weather conditions.

PGR treatment reduced plant height with all treatment rates of XE-1019 (Table II-6) in 1987, even though the warmer and drier conditions caused reduced crop growth. Earlier applications of XE-1019 shortened final canopy height more than later treatments. In contrast, Parlay-treated plants responded to the later treatment with reduction in plant height than the earlier-treated. Stem length, mean internode length, and internode number were not affected by foliar applications in 1987, although stem length and mean internode length (Table II-7) appeared to shorten with PGR treatments as observed in canopy height measurements from Table II-6.

Total dry weight and straw yield in 1987 were reduced ($p<0.10$) by of XE-1019 applied at both application times and by prebloom application of Parlay (Table II-8). Later applications of both XE-1019 and Parlay also reduced seed weight indicating potential phytotoxicity.

DISCUSSION

Results in 1986 show improved seed yield from foliar application of PGRs. Furthermore, seed yield increases resulting from inflorescences per unit area in 1986 warranted further investigation of application timing to identify an optimum time of application. Therefore, foliar treatments in 1987 were modified to determine when a foliar application would be most effective. Other research has also shown an increase in inflorescence number with foliar-applied Parlay treatments (Niemelainin, 1987) when applied at first inflorescence emergence. PGR applications in 1987 were done at both canopy closure and at prebloom to test the effect of later application timing on crop growth and seed production.

Height response in 1987 to the Parlay treatment at canopy closure (Table II-6) was similar to that observed in 1986 (Table II-1). Shortening of the third to fifth internode in the 1986 experiment probably occurred shortly after application of the foliar-applied PGRs indicating that foliar and/or stem uptake was effective. Fewer internodes Parlay-treated plants also contributed to shorter stem lengths. XE-1019 had longer lasting effect on height in both years when applied at canopy closure. Research conducted in Norway (Niemelainin, 1987) also reported that Parlay shortened stems, although the effect was not as great in this study.

Minor effects on total dry matter and straw yield should be expected since application of PGR treatments occurred well into regrowth. Late applications may have more effect on the reproductive development than on canopy growth and development.

In 1986, Parlay-treated plots averaged 26 kg/ha more than XE-1019-treated plots and 131 kg/ha more than the untreated check. Seed yields in 1987 averaged 40 kg/ha less in the XE-1019-treated plots and 36 kg/ha less in the Parlay-treated plots than in the untreated check (Table II-8). In addition, late application of XE-1019 and Parlay reduced yields by 20 kg/ha over earlier application at canopy closure.

XE-1019 reduced straw production more than Parlay in 1986, thereby increasing harvest index more than Parlay without higher seed yields.

In years with adequate moisture for growth, foliar PGR applications improve seed yield as was observed in 1986. Though dry matter and plant height were not greatly affected by foliar PGR application, the improvement in seed yield was important. Use of foliar-applied PGRs should work with crops grown under non-irrigated management without the necessary application of water as required for soil-applied PGRs. Early applications produced better results than late applications but in conditions of drought like 1987, both PGRs reduced seed yield.

Table II-1. Canopy height of red clover seed crops treated with foliar-applied PGRs, 1986.

	Sampling date				Height change		
Treatment rate	June 30	July 9	July 17	August 25	June 30-July 9	July 9-July 17	July 17-August 25
kg ai/ha	cm						
Check	34.3	46.4	51.2	57.2	12.2	4.8	6.0
XE-1019							
0.07	33.8	43.9	46.3	55.3	10.2	2.4	9.0
0.14	31.5	41.6	47.0	53.3	10.1	5.4	6.3
0.28	33.3	43.8	43.3	52.2	10.5	-0.5	8.8
0.56	36.5	43.3	43.8	51.8	6.8	0.6	8.0
1.12	33.7	42.6	41.2	49.9	8.9	-1.4	8.8
Parlay							
0.28	31.4	44.2	47.0	54.8	12.8	2.8	7.8
0.56	33.8	45.1	46.5	54.6	11.3	1.4	8.1
1.12	34.6	43.9	46.2	52.4	9.3	2.3	6.3
1.68	32.1	44.4	45.2	55.2	12.3	0.8	10.0
LSD 0.05	NS	NS	3.8	NS	3.1	4.0	NS
P-value			0.001		0.009	0.031	
Mean	33.5	43.9	45.8	53.7	10.4	1.9	7.9

Table II-2. Reproductive stem measurements in red clover seed crops treated with foliar-applied PGRs, 1986.

Treatment rate	Stem length	Mean internode length	Internode
kg ai/ha	---------------- cm	----------------	no.
Check	57.0	9.0	6.4
XE-1019			
0.07	49.8	8.2	6.1
1.12	46.2	7.6	6.1
Parlay			
1.12	51.1	9.5	5.4
LSD 0.05	4.6	1.2	0.7
P-value	0.001	0.021	0.050
Mean	51.0	8.6	6.0

Table II-3. Reproductive stem internode lengths in red clover seed crops treated with foliar-applied PGRs, 1986.

Treatment	Internode					
rate	Top	2	3	4	5	6
kg ai/ha	cm					
Check	4.8	9.5	12.2	13.2	10.6	7.0
XE-1019						
0.07	4.9	8.9	11.0	11.0	9.4	7.0
1.12	3.8	7.3	9.8	10.7	9.8	6.4
Parlay						
1.12	6.0	10.4	12.2	12.0	10.0	5.6
LSD 0.05	NS	NS	1.8	1.5	1.3	NS
P-value			0.032	0.010	0.009	
Mean	4.9	9.0	11.3	11.7	10.0	6.5

Table II-4. Total dry weight, straw yield, seed yield, harvest index, and seed weight in red clover seed crops treated with foliar-applied PGRs, 1986.

Treatment rate	Plot dry weight	Straw yield	Seed yield	Harvest index	Seed weight
kg ai/ha	------------------- kg/ha	----------------------		%	mg
Check	5835	5209	627	10.8	1.60
XE-1019					
0.07	5843	5732	713	12.2	1.58
0.14	5587	4917	671	12.1	1.57
0.28	5934	5192	742	12.5	1.58
0.56	5925	5148	778	13.1	1.59
1.12	5789	5033	757	13.0	1.53
Parlay					
0.28	5876	5210	667	11.4	1.58
0.56	6129	5348	780	12.8	1.58
1.12	6024	5199	826	12.0	1.60
1.68	6366	5607	759	12.0	1.60
LSD 0.05	NS	NS	99	1.6	0.04
P-value			0.006	0.018	0.038
Mean	5932	5199	732	12.4	1.58

Table II-5. Yield components in red clover seed crops treated with foliar-applied PGRs, 1986.

Treatment rate	Inflore-scences	Fertile stems	Inflorescenses per stem	Calyx per head	Seed number Potential	Seed number Actual	Floret site utili-zation
kg ai/ha	----- no./30 cm -------		--------- no. ---------		---- no. X $10^3/m^2$ ----		%
Check	69	28	2.4	110	46.1	21.7	53
XE-1019							
0.07	92	29	3.2	111	61.6	25.1	44
0.14	102	27	4.2	111	67.8	23.9	37
0.28	81	26	3.0	117	57.8	26.1	52
0.56	112	30	3.6	121	82.0	27.3	41
1.12	103	29	3.6	113	71.1	27.4	43
Parlay							
0.28	86	28	3.1	118	61.0	23.5	41
0.56	88	27	3.3	120	61.6	27.3	47
1.12	112	29	4.0	114	76.0	28.6	38
1.68	103	27	3.8	113	69.4	26.3	41
LSD 0.05	25	NS	0.9	NS	18.5	3.5	NS
P-value	0.026		0.024		0.046	0.007	
Mean	95	28	3.4	115	65.4	25.7	44

Table II-6. Canopy height of red clover seed crops treated with foliar-applied PGRs, 1987.

Time of application during regrowth		Sampling date				Height change		
Canopy closure	Prebloom	July 2	July 10	August 7	August 28	July 2-July 10	July 10-August 7	August 7-August 28
---------- kg ai/ha -----------		-- cm				-------------------------------------		
Check		31.3	30.4	41.3	45.3	-0.9	10.9	4.0
XE-1019								
0.28	---	30.3	28.0	40.1	38.5	-2.3	12.1	-1.6
---	0.28	31.0	30.0	38.9	37.1	-1.0	8.9	-1.7
0.56	---	28.0	28.0	33.0	35.3	0.0	5.0	2.3
---	0.56	27.8	27.5	35.4	38.0	-0.3	7.9	2.6
1.12	---	26.8	27.9	32.1	34.0	1.1	4.3	1.9
---	1.12	27.9	29.9	34.1	40.8	2.0	4.3	6.6
Parlay								
0.56	---	29.6	28.6	39.0	41.8	-1.0	10.4	2.8
---	0.56	27.1	28.0	35.3	37.8	0.9	7.3	2.5
0.84	---	28.0	29.5	33.9	41.8	1.5	4.4	7.9
---	0.84	28.8	30.5	37.4	38.5	1.8	6.9	1.1
1.12	---	27.9	30.5	35.5	40.3	2.6	5.0	4.8
---	1.12	28.3	27.5	36.3	37.0	-0.8	8.8	0.8
LSD 0.05		NS	NS	5.6	5.7	NS	5.4	NS
P-value				0.047	0.027		0.042	
Mean		28.7	28.9	36.3	38.9	0.3	7.4	2.6

Table II-7. Reproductive stem measurements in red clover seed crops treated with foliar-applied PGRs, 1987.

Time of application during regrowth: Canopy closure	Prebloom	Stem	Mean Internode	Internode
----------- kg ai/ha -----------		------------- cm ------------		no.
Check		33.5	5.2	6.5
XE-1019				
1.12	---	28.3	4.7	6.1
---	1.12	27.1	4.6	5.9
Parlay				
1.12	---	32.2	5.0	6.4
---	1.12	30.3	4.7	6.6
LSD 0.05		NS	NS	NS
Mean		30.3	4.8	6.3

Table II-8. Total dry weight, straw yield, seed yield, harvest index, and seed weight in red clover seed crops treated with foliar-applied PGRs, 1987.

Time of application during regrowth: Canopy Closure	Prebloom	Total dry weight	Straw yield	Seed yield	Harvest index	Seed weight
-------- kg ai/ha ---------		--------------- kg/ha ---------------			%	mg
Check		3157	2982	175	5.4	1.84
XE-1019						
0.28	---	3129	2955	174	5.8	1.84
---	0.28	2944	2803	142	4.6	1.80
0.56	---	2280	2142	138	6.0	1.84
---	0.56	2260	2160	100	4.4	1.76
1.12	---	2058	1934	126	6.3	1.82
---	1.12	2276	2147	129	5.6	1.72
Parlay						
0.56	---	2932	2773	158	5.4	1.85
---	0.56	2219	2093	126	5.6	1.80
0.84	---	2629	2483	145	5.4	1.83
---	0.84	2637	2512	124	4.7	1.79
1.12	---	2982	2837	145	4.8	1.82
---	1.12	2465	2327	138	5.5	1.78
LSD 0.05		NS	NS	NS	NS	0.05
P-value						<0.001
Mean		2613	2473	140	5.3	1.81

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SUMMARY AND CONCLUSIONS

It is evident that the PGRs used in this study have excellent potential for improving harvest index and seed yield. Both XE-1019 and Parlay decreased plant height and total dry matter production while at the same time increasing seed yields and harvest index.

XE-1019 was more effective than Parlay in decreasing height, total dry weight, and straw weight. In contrast, Parlay was more effective than XE-1019 at increasing seed yield, the most important single factor in assessing the potential use of these PGRs for agronomic purposes. From these results Parlay appears to have other benefits that could be related to the fungicidal components while XE-1019 is a much more effective growth retardant.

XE-1019 treatments gave the best yield response at treatment rates of 0.14 to 0.56 kg ai/ha while Parlay gave the best seed yield response at treatment rates of 1.12 to 1.68 kg ai/ha. It appears that benefits from the use of Parlay and XE-1019 are enhanced with adequate moisture. The normal precipitation year (1986) resulted in improved seed yields with both soil and foliar-applied PGRs in contrast to a dry year (1987) when PGR applications were not beneficial.

Research with carefully monitored irrigation management is needed to identify the maximum benefit that can be derived from chemical regulation of plant growth in irrigated red clover seed production. In addition, more research is needed to evaluate the response of red clover at different growth stages to foliar applications of triazole-type PGRs. Finally, actual combine harvest trials are needed in order to accurately determine whether any improvement in harvest conditions (including time needed to swath, dry, and combine) can be attained with PGRs. Improved seed recovery may be possible because PGR-treated plants produce less vegetative dry matter to process through the combine.

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APPENDIX

APPENDIX I

Table A-1. 1987 weather data, Corvallis, Oregon (Redmond, 1987)

Month	Air temperature	Standard deviations from 30 year mean	Rainfall	Departure from 30 year mean	Pan evaporation	
					Actual	30 year mean
	°C	no.	cm	cm	cm	cm
March	8.5	1.3	9.4	-2.4	---	---
April	11.5	1.6	4.0	-2.3	8.6	7.0
May	14.5	1.6	3.6	-1.3	12.4	11.3
June	17.5	1.3	0.7	-2.3	19.6	14.5
July	18.4	-0.2	5.7	+4.9	17.3	19.8
August	19.9	1.0	0.4	-1.6	21.0	17.8