EFFECT OF SPRING DEFOLIATION AND TRINEXAPAC-ETHYL (PALISADE EC) PLANT GROWTH REGULATOR ON ANNUAL RYEGRASS SEED CROPS

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Introduction

Annual ryegrass (*Lolium multiflorum* L.) is a forage and restoration crop globally and an important seed crop in Oregon. Current seed yields in annual ryegrass are only 15–33% of potential. One of the major reasons for yield reduction is lodging during anthesis, which reduces successful pollination and fertilization. Using field management techniques that reduce lodging could increase seed yields.

The plant growth regulator (PGR) trinexapac-ethyl (TE), trade name Palisade EC, has been shown to reduce lodging by inhibiting gibberellic acid receptors when applied at the two-node growth stage (BBCH 32). This inhibition reduces stem elongation and spike length in annual ryegrass plants, while retaining the same number of spikelets as untreated plants (Chastain et al., 2014; Chastain et al., 2015). The reduction has been shown to increase seed yield in annual ryegrass (Trethewey et al., 2016).

Defoliation has been shown to be an effective tool to combat lodging when timed strategically (Rolston et al., 2010). When defoliation is combined with PGRs, lodging can be further reduced (Rolston et al., 2012), especially in crops that produce a large amount of above-ground biomass, such as annual ryegrass. Current PGR recommendations are 3.0 pt Palisade EC/acre on annual ryegrass seed crops in Oregon. This recommendation has had positive effects on Oregon's annual ryegrass seed yields (Anderson et al., 2023). The aim of this study was to determine whether there is an effective upper limit to the Palisade EC application rate on annual ryegrass with and without spring defoliation by mowing or grazing.

Materials and Methods

Annual ryegrass (cv. 'Gulf') was planted at a rate of 10 lb/acre in 10-inch row spacings at Oregon State University's Hyslop Research Farm in October 2022. The experiment was organized in a randomized complete block with a split plot design. The main plots (spring defoliation treatments) were 55 feet x 50 feet, while the subplots (Palisade EC treatments) were 11 feet x 50 feet. Fertilizer was applied and incorporated (40 lb N/acre of 33-0-0-12) prior to planting, followed by application in the spring (140 lb N/acre of 40-0-0-5) when 200 growing degree days had accumulated. Routine herbicide treatments were applied as needed for management of grass and broadleaf weeds.

Spring defoliation treatments were carried out two times using a tractor-mounted 8-foot flail mower set to a 3-inch cutting height. The first defoliation treatment was applied when plants initially reached the two-node stage (BBCH 31–32) on April 14. The second defoliation was applied once the plants had regrown to the two-node stage on April 25.

Palisade EC was applied at a rate of 0 (untreated control), 2, 4, 6, and 8 pt/acre using a custom-built bicycle sprayer. The nondefoliated plots were treated with Palisade EC at the two-node stage on April 25. Plots that received the spring defoliation treatment were allowed to regrow to the two-node stage after the second flailing before they received the Palisade EC treatments on May 3.

At peak flowering (BBCH 65), two 1 ft^2 biomass samples were collected randomly (cut 2 cm above ground level) from each plot and placed in a drying room set at 48.9° for 24 hours. The dry biomass samples were then weighed to determine total above-ground biomass, and fertile tillers were counted. Ten fertile tillers were randomly selected from each sample to determine average tiller length and spike length. Percent lodging ratings were taken just prior to swathing on June 16.

Seed moisture was monitored separately for defoliation and no-defoliation plots because crop maturity was noticeably different between the two. Once seed moisture reached 45%, the plots were swathed using a modified John Deere 2280 swather (no-defoliation treatments, June 20, 2023; defoliation treatments, June 22, 2023). All plots were harvested on June 28, 2023 using a Hege 180 plot combine.

Harvest weights were recorded, and subsamples were collected from harvested seed. Seed was cleaned using a Clipper M2B cleaner to determine percent cleanout and to calculate clean seed yield. Two subsamples were collected from harvested seed to determine 1,000-seed weight using an electric seed counter and laboratory balance. Once these weights were determined, harvest index (HI), the ratio of seed yield to above-ground biomass, was calculated.

An analysis of variance (ANOVA) for a randomized complete block was performed using the program Statistix 10 (Analytical Software). Statistical groups were determined using an LSD of 0.05.

Results and Discussion
Results from the ANOVA indicated no interaction for seed yield between spring defoliation and PGR treatments ($P = 0.1071$) (data not shown). This was surprising, as previous studies have reported strong interactions between the two spring management practices (Anderson et al., 2019). Interactions occurred only for seed number ($P = 0.0307$) and lodging ($P = 0.0000$).

In the current study (results shown in Table 1), the no-defoliation treatment resulted in a 19.5% seed yield increase compared to the spring defoliation treatment. Interestingly, cleanout was 21.5% higher in the no-defoliation plots compared to the defoliation treatment, which likely accounts for the higher clean seed yield in the no-defoliation treatment. Seed weight and seed number were both greater with no defoliation, by 8.6 and 13.4%, respectively.

Not surprisingly, the no-defoliation treatment had 44.7% more total above-ground biomass compared to the defoliation treatment, resulting in the defoliation treatment having a 48% higher HI. While there was no difference in number of fertile tillers between spring defoliation treatments, results showed fertile tiller height and spike length to be 29.3% and 10.6% shorter, respectively, when spring defoliation occurred. The reduction in fertile tiller height likely resulted in 48% less lodging in the defoliation treatment.

The application of TE PGRs (Palisade EC) increased clean seed yields by 29.4% compared to the untreated control. There were no differences in seed yield among the Palisade EC rates (2, 4, 6, and 8 pt/acre). Palisade EC rates at 4 pt/acre or higher resulted in more cleanout than the untreated control and 2 pt/acre Palisade treatment. Seed weights were reduced by all Palisade EC rates; however, seed number was increased with all Palisade EC rates, likely contributing to the increase in seed yield from PGR applications. These results further validate the hypothesis that seed number influences seed yield more than seed weight in cool-season grass seed crops.

All Palisade EC applications increased fertile tiller number and decreased spike length, compared to the untreated control. Although there were no differences in total above-ground biomass among PGR treatments, the HI was 25.9% greater when Palisade EC was applied. This is an indication of greater reproductive efficiency when TE-containing PGRs are used in annual ryegrass seed crops. Tiller height reduction was correlated to Palisade EC rate. The higher the Palisade EC rate, the

Table 1. Effect of spring defoliation and trinexapac-ethyl plant growth regulator (PGR)[1] on seed yield and growth components in ‘Gulf’ annual ryegrass, 2022.

	Seed yield	Cleanout	Seed weight	Seed number	Biomass	Fertile tillers	Tiller height	Spike length	HI[2]	Lodging (June 16)
	(lb/a)	(%)	(mg seed^{-1})	(no m^{-2})	(kg ha^{-1})	(no ft^{-2})	(cm)	(cm)	(%)	(%)
Spring defoliation treatment										
No mow	2,583.0 b	2.33 b	2.69 b	110,296 b	14,924 b	120	97.0 b	17.8 b	19.9 a	67.0 b
2X mow	2,079.0 a	1.83 a	2.46 a	95,547 a	8,260 a	132	68.6 a	15.9 a	29.4 b	42.2 a
$P =$	0.0047	0.0388	0.0493	0.0156	0.0008	0.1221	0.0034	0.0026	0.0015	0.0284
PGR treatment										
Untreated control	1,685.4 a	1.73 a	2.96 d	64,147 a	11,303.0	102 a	114.5 d	20.1 e	18.1 a	94.4 d
Palisade EC 2 pt/a	2,386.8 b	1.59 a	2.66 c	100,543 b	11,541.0	116 ab	88.1 c	17.8 d	24.7 b	83.1 c
Palisade EC 4 pt/a	2,596.2 b	2.31 b	2.51 b	115,465 c	12,978.0	141 c	79.9 bc	16.6 c	24.3 b	49.4 b
Palisade EC 6 pt/a	2,548.0 b	2.34 b	2.41 a	118,139 c	11,280.0	134 bc	70.9 b	15.3 b	29.0 b	25.6 a
Palisade EC 8 pt/a	2,438.1 b	2.43 b	2.35 a	116,313 c	10,858.0	138 c	60.9 a	14.0 a	27.0 b	20.6 a
$P =$	0.0000	0.0000	0.0000	0.0000	0.3614	0.0019	0.0000	0.0000	0.0134	0.0000

[1]Palisade EC
[2]Harvest index (HI) is the ratio of seed yield to above-ground biomass.

shorter the tiller, resulting in less lodging. The 8-pt Palisade EC/acre rate reduced lodging by 73.8%.

Previous studies conducted in Oregon have shown a seed yield interaction between spring defoliation and PGRs. The weather conditions in the spring of 2022 were abnormally cool, and biomass accumulation was less than normal. It is possible that less total above-ground biomass contributed to a lack of interaction between the two spring management practices. There also appears to be a correlation between spike length and seed number, as well as between spike length and seed yield. It would be interesting to quantify seed shattering among PGR treatments that result in different spike lengths to determine whether a more compact spike contributes to less seed loss at harvest and higher seed yields. Overall, it is apparent that the use of TE-containing PGRs, such as Palisade EC, increase seed yield and should be considered for use in Oregon's annual ryegrass seed crops, regardless of whether spring defoliation occurs or not.

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