EFFECTS OF THE PLANT GROWTH REGULATOR CHLORMEQUAT CHLORIDE ON FINE FESCUE SEED YIELD AND YIELD COMPONENTS

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Introduction
Several fine fescue grass seed crops (*Festuca rubra* L.) are produced in Oregon: strong creeping red fescue (*Festuca rubra* ssp. *rubra*), slender creeping red fescue (*Festuca rubra* ssp. *littoralis*), and Chewings fescue (*Festuca rubra* ssp. *commutata*). Fine fescues are used extensively as turf grasses and are valued for their broad adaptability to many climates, their slender leaves, and their low input requirements. In Oregon, fine fescues are grown in parts of northeastern Oregon and in the Silverton Hills of the Willamette Valley. Oregon production of Chewings and red fescue species was valued at approximately $27 million in 2020.

The benefits of the plant growth regulator (PGR) trinexapac-ethyl (TE; Palisade EC) in Oregon fine fescue seed production has been demonstrated since the early 2000s (Gingrich and Mellbye, 2001), and spring application of TE is now a standard practice.

In 2015, field research was initiated in Oregon to investigate the possible utility of another plant growth regulator, chlormequat chloride (CCC; Adjust), in grass seed crops, including fine fescue. As with TE, CCC acts on the gibberellin biosynthesis pathway, which reduces stem length. However, CCC acts at an earlier point in the pathway (Rademacher, 2015). Chlormequat chloride has been used successfully for decades in other grass-seed-producing regions of the world, but it has not been registered for use in grass seed crops in the United States. Across grass species, the most consistently successful use pattern for CCC has been in combination with TE. A federal registration is currently being sought for use in grass grown for seed, and, if registered, the new CCC product is anticipated to be available as a much more concentrated and affordable product relative to existing horticultural formulations.

Multiyear field trials looking at CCC in combination with TE in Chewings and creeping red fescue were conducted between 2018 and 2020 (Anderson et al., 2021). Results indicate that in first- and second-year Chewings fescue, seed yield increased significantly when TE + CCC was applied compared to TE alone or an untreated control. In creeping red fescue, no additional benefit over TE alone was observed.

A study in Poland also found that CCC combined with TE increased average yields of Chewings and creeping red fescues by 9.3% (Szczepanek et al., 2021). Yield increases were attributed to both increased number of spikelets per panicle and reduced lodging. In related studies, CCC alone, or in combination with TE, reduced fertile tiller height in Chewings fescue, which was reportedly more responsive to plant growth regulators than creeping red fescue (Szczepanek et al., 2020).

To date, trial work with CCC in Oregon has been limited to lower rates, 1.3 lb a.i./acre or less, given the high cost and high application volumes of the currently available product (Cycocel, registered for use in ornamental nursery production). The main objectives of this study were the following:

- To further evaluate the efficacy of CCC in combination with TE to increase seed yield in Chewings fescue.
- To test whether higher rates of CCC in combination with TE provide an additional yield response in Chewings fescue.

Materials and Methods
This study was conducted on two established commercial Chewings fescue seed production fields located in the Silverton Hills. Both were planted in spring 2019, harvested in 2020, and open field burned following the first seed harvest in 2020. Work for this trial was conducted during the 2021 growing season, corresponding to the second year of seed harvest for each field. Site 1 was planted to variety 'Leeward', and Site 2 was planted to variety 'Momentum'. A randomized complete block design was utilized at each site with three replicates and individual plot sizes of 25 feet x 300 feet at Site 1 and 29 feet x 300 feet at Site 2. Each trial was fertilized in early spring by the grower at standard nitrogen rates, and a standard fungicide (Trivapro at 21 oz/acre) was applied at the time of PGR application.

Plant growth regulators were applied on April 22, 2021 using an ATV-mounted spray unit with a 29-foot boom calibrated to deliver 17.5 gpa. The growth stage at the time of PGR application corresponded to early stem elongation stage, or two-node stage (BBCH 32). The

OSU recommended rate of TE (1.4 pt/acre) was tested alone and in combination with three rates of CCC. Since this same TE rate was used in all treatments containing a PGR, we have simplified the names in the results and discussion text to TE or TE + CCC and the CCC rate. Treatments included the following PGR rates and combinations:

- Untreated control
- TE (TE 1.4 pt/acre)
- TE + CCC 1.3 (TE 1.4 pt/acre + CCC 1.3 lb/acre)
- TE + CCC 2.6 (TE 1.4 pt/acre + CCC 2.6 lb/acre)
- TE + CCC 3.9 (TE 1.4 pt/acre + CCC 3.9 lb/acre)

Above-ground biomass samples were collected June 7 during the period of peak flowering to end of flowering (BBCH 65–69) by taking three 1-ft^2 quadrat samples from random locations within each plot. Subsamples were then aggregated into a single composite sample from each plot and were analyzed for biomass and tiller height.

The middle of each plot was harvested with commercial equipment (swather and combine), equating to a harvest plot size of 14.5 feet x 300 feet and 16 feet x 300 feet at Site 1 and 2, respectively. Site 1 was swathed on June 29 and harvested on July 10, and Site 2 was swathed on July 6 and harvested on July 17. Dirt seed yield was determined with a weigh wagon. A subsample of harvested seed from each plot was cleaned to determine clean seed yield, percent cleanout, and seed weight (mg/seed). Harvest index (HI) was calculated as the seed yield relative to above-ground biomass for a given area, and number of seed per square meter was calculated from clean seed yield and seed weight.

Results and Discussion

Seed yield was higher than the untreated control when CCC, at all rates, was added to TE at Site 1, but yield showed no effect at Site 2 at any rate (Table 1). There was no effect of CCC rate on seed yield at either site. Application of TE alone did not affect seed yields at either site.

The addition of CCC reduced tiller height relative to untreated controls at both sites. At Site 1, TE + CCC 2.6 and TE + CCC 3.9 reduced tiller height relative to TE alone. At Site 2, all rates of CCC reduced tiller height relative to TE alone. Despite differences in tiller height, a significant reduction in above-ground biomass was not observed at either site. High variability was observed in above-ground biomass quadrat data, and this limited our ability to discern differences.

Harvest index (HI) is the ratio of seed yield to above-ground biomass. A higher HI means the crop had more seed production relative to above-ground biomass and can be thought of as indicating greater efficiency

Table 1. Effect of trinexapac-ethyl (TE) and chlormequat chloride (CCC) mixes on seed yield, cleanout, seed weight, seed number, above-ground biomass, tiller height, and harvest index of Chewings fine fescue.[1]

Treatment	Yield	Cleanout	Seed weight	Seed number	Biomass	Tiller height	Harvest index
	(lb/a)	(%)	(mg/seed)	(no/m^2)	(ton/a)	(cm)	(%)
				Site 1			
Untreated control	1,683 a	7.5 a	0.9569 a	213,102	8.4	86.0 c	10.0 a
TE 1.4 pt/a	1,840 ab	6.7 ab	0.9693 ab	228,360	7.3	77.3 bc	12.9 ab
TE 1.4 pt/a + CCC 1.3 lb/a	1,985 b	6.4 ab	1.0056 b	236,443	6.9	66.5 ab	14.7 ab
TE 1.4 pt/a + CCC 2.6 lb/a	1,957 b	5.9 b	0.9964 ab	234,210	6.8	61.1 a	14.5 ab
TE 1.4 pt/a + CCC 3.9 lb/a	2,002 b	5.5 b	1.0059 a	236,525	6.7	63.3 a	15.2 b
				Site 2			
Untreated control	1,795	9.3	0.9885	224,264	5.4	80.5 c	16.7
TE 1.4 pt/a	1,804	10.1	0.9952	225,878	5.4	69.1 b	16.7
TE 1.4 pt/a + CCC 1.3 lb/a	1,843	10.2	1.0014	229,135	5.0	56.2 a	18.3
TE 1.4 pt/a + CCC 2.6 lb/a	1,870	10.0	0.9957	233,687	4.9	56.5 a	19.5
TE 1.4 pt/a + CCC 3.9 lb/a	1,764	9.8	1.0027	218,346	5.4	56.2 a	16.7

[1]Data for each site were analyzed separately. Numbers followed by the same letter are not significantly different at LSD ($P = 0.05$). If no letters are present in a column, no significant differences were observed.

at allocating resources to seed production versus vegetative growth. At Site 1, only the highest CCC rate, TE + CCC 3.9, increased HI relative to the untreated control.

Seed weight was typical for Chewings fescue and ranged from 0.957 to 1.006 mg/seed across sites (Table 1). At Site 1, seed weight was higher with the TE + CCC 1.3 rate relative to the untreated control. This was not the case, however, for the higher CCC rate combinations, and no clear pattern emerged in seed weight. At Site 2, there was no effect of any PGR treatment on seed weight. Percent cleanout was not affected by PGRs at Site 2, but at Site 1 higher rates of CCC reduced cleanout relative to an untreated control. There was no effect of any PGR treatment on seed number.

Overall, the addition of CCC to the PGR mix was more effective at Site 1. At Site 2, we saw no effect of any PGR combination on yield or yield components, with the exception of tiller height, which was reduced by the application of TE and further reduced with the addition of CCC (Table 1). The lack of effects at Site 2 may relate to the variety and/or time of application relative to growth stage, or to minor environmental differences between the sites. Site 2 was at a slightly higher elevation, and, while both crops were at BBCH 32 at the time of PGR applications, Site 2 was on average about 1 week delayed in maturity relative to Site 1. Moisture stress and underlying differences in soil water content between the two sites also may have played a role. The spring of 2021 was the sixth driest spring since weather records began in 1889. Rainfall between March and June 2021 was less than half of normal for that time period, and it was exceptionally low in April and May.

We observed a small improvement in some yield components with a higher CCC rate, for example, lower tiller height, lower cleanout, and higher HI, but these did not translate to higher yields. To date, the data do not show an added benefit from higher CCC rates. However, in a year with less drought stress and higher biomass growth potential, the improved stem shortening observed at higher CCC rates could be beneficial in preventing lodging.

Overall, results show that the addition of CCC as a tank-mix partner with TE can increase yields relative to an untreated control in some cases, but results may be inconsistent due to weather, field location, or varietal response. It is not yet clear whether the additional benefit of CCC beyond TE alone will be consistent or large enough to provide a reliable return on investment. For example, at Site 1 the addition of CCC tended to increase yields by 140 lb/acre on average, compared to TE alone, but these differences were not statistically significant. No negative effects of TE alone or in combination with CCC were observed, despite extremely dry spring conditions.

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