Annotated Bibliography – Plant growth regulators (particularly trinexapac-ethyl) and cool-season grass seed crops and legume seed crops

Note: the summaries compiled under each reference contain 'cut and paste' information from the authors' abstracts/conclusions/articles in general and blog sites, and as such may need to be altered depending on how this document is used [or perhaps this note is enough]. Council of Science Editors (CSE) Documentation style is used below.

Aamlid TS, Havstad LT. [Internet]. 2011. Herbage seed production based on Norwegian experiment and practice. Norway: Norwegian Institute of Bioeconomy Research; [accessed February 24, 2016]. Available from: http://www.bioforsk.no/ikbViewer/Content/95468/Estland_dec2011%20tsaa%20compessed.pdf.

Pages 9 and 10 of this document are particularly useful as they pertain to growth regulator use (chlormequat chloride [CCC] and trinexapac-ethyl [TE]) and research done on timothy, meadow fescue and diploid red clover. Also discusses, cocksfoot, smooth bromegrass, perennial ryegrass, red canary grass, creeping red fescue, colonial bent and Kentucky bluegrass. The authors also note the ability to tank mix fungicides with growth regulators in wet spring conditions (pg. 11). Cycocel (CCC) and Moddus (TE) are registered for use in seed production in Norway. They are used to reduce stem elongation and increase seed yield. They suggest that these PGRs (particularly Moddus) not be used in adverse conditions (drought, night frost, tough herbicide application). Their research included using a combination of the two PGRs mentioned above on timothy, which gave a better result than using just one or the other.

Anderson NP, Chastain TG, Garbacik CJ. 2016. Irrigation and trinexapac-ethyl effects on seed yield in first- and second-year red clover stands. Agron. J. 108 (In press)

Likely useful but unable to access this article.

Anderson NP, Chastain TG, Garbacik CJ. 2015a. Irrigation and trinexapac-ethyl effects on seed yield in first- and second-year red clover stands. In Anderson N, Hulting A, Walenta D, Flowers M, Sullivan C, editors. 2014 Seed Production Research Report. Oregon State University: Ext/CrS 151.

This article is the third in a series regarding irrigation and trinexapac-ethyl (TE) effects on red clover (see Chastain et al, 2013 and 2014 below). This study looked at first and second year red clover stands and took place over 3 years.

Key findings:

- Irrigation consistently increased seed yield across both stand ages and years
- Seed yield was not affected by application of TE at any rate or timing in first-year stands, regardless of year
- Red clover seed yield was increased by application of TE at BBCH 32 only in second-year stands; TE applied at BBCH 32 produced seed yield increases of 15 to 19% in second-year red clover seed stands; seed yield was likely due to increased inflorescences
- Seed weight was reduced by TE regardless of application timing or rate, but the decline in seed weight was more pronounced when TE was applied at BBCH 50.
- When TE was applied early (BBCH 32), the harvest index generally increased with increasing application rate. When TE was applied at BBCH 50, the harvest index decreased as the TE rate was increased.
- Irrigation and TE can independently increase seed yield in red clover seed crops, but there was no interaction between the two
- A first- or second-year stand likely will benefit from a single irrigation; however, data from this study indicate that, under Oregon conditions, TE likely will increase seed yield only when applied at BBCH 32 in second-year stands

Anderson NP, Chastain TG, Garbacik CJ, Silberstein TB. 2012. Effect of foliar applications of trinexapac-ethyl plant growth regulator on red clover seed crops. In Young III WC, editor. 2011 Seed Production Research Report. Oregon State University: Ext/CrS 136.

This article discusses a two year study (2010 and 2011) which looked at the effect of trinexapac-ethyl on red clover. Application rates were varied as was timing. Application timing occurred at BBCH 32 (stem elongation) or BBCH 50 (bud emergence) as well as a split application at BBCH 32 and GS 50.

Key findings of the article:

- In 2010, TE treatments increased red clover seed yields by 15 to 34 percent above the untreated control. Seed yield was significantly increased by TE when applied late at 1.7 pt/acre or when 3.4 pt/acre was split between early and late timings.
- In 2011, TE increased seed yield by 5 to 13 percent above the untreated control. Three of the four TE treatments significantly increased red clover seed yield. In both years, the split 1.7 pt/acre treatment ranked among the best for increasing seed yield.
- Thousand seed weight was inversely related to seed yield; treatments producing highest seed yield had the lowest seed weight.
- The cause of the seed yield increase seems to come from several factors including increased production of seed heads and reduction of canopy height.
- Field observations over the two years of on-farm trials indicate that in addition to increasing seed yield, TE treatments also promoted earlier maturation of the crop thereby allowing more timely harvest operations.
- The early 3.4 pt/acre treatment reduced canopy height, and that tendency was evident but not significant in other TE treatments.

Anderson NP, Monks DP, Chastain TG, Rolston MP, Garbacik CJ, Chun-hui Ma, Bell CW. 2015b. Trinexapac-ethyl effects on red clover seed crops in diverse production environments. Agron. J. 107:951-956.

(Taken from the Oregon State university seed blog page, http://blogs.oregonstate.edu/seedproduction)

Key findings of the article:

- Trinexapac-ethyl was responsible for seed yield increases in red clover ranging from 9 to 15% in New Zealand and Oregon's Willamette Valley.
- One contributing factor for the increased seed yield with trinexapac-ethyl was that the PGR increased the number of heads formed in the red clover crop. Moreover, the PGR reduced the height of the crop canopy and increased penetration of light into the canopy, possibly leading to the increased head production.
- Timing of trinexapac-ethyl applications to coincide with early stem elongation gave the best seed yields although split applications at stem elongation and bud emergence produced yield increases in Oregon.
- Seed weight was generally inversely related to yield; trinexapac-ethyl treatments that produced the highest yield also had the lowest seed weight.
- (Added by S Kirk, from article abstract) Crop height was consistently reduced by TE across CA and OR environments but aboveground crop biomass was not affected by TE.

Angsumalee D, Elias SG, Anderson NP, Chastain TG, Garbacik CJ. 2014. Effect of plant growth regulators and irrigation on physiological maturity and seed quality of red clover. In Anderson N, Hulting A, Walenta D, Flowers M, editors. 2013 Seed Production Research Report. Oregon State University: Ext/CrS 150.

This study was performed over 2011 and 2012 and looked at the effect on physiological maturity and seed quality of PGRs trinexapac-ethyl and prohexadione calcium (PC) on both irrigated and non-irrigated plots of red clover. [According to the authors there will be a second report on this study, though I did not find it so perhaps it is not out yet]

Key findings:

- The TE and PC application rates had no significant effects on seed moisture content
- The TE application reduced seed dry weight, while PC did not
- Year one results did not indicate that TE treatments promoted earlier seed maturation as was expected
- Results from year one of this work indicated that seed yield was increased by irrigation but was not significantly affected by PGR treatments

[APVMA] Australian Pesticides and Veterinary Medicines Authority. [Internet]. 2013. Trade advice notice on trinexapac-ethyl in the product Moddus Evo yield & quality enhancer. Australia: APVMA; [accessed March 2, 2016]. Available from: www.apvma.gov.au.

Contains information on TE residue allowances for cereal crops and animal products for many countries. No information on grass or legume seed crops though.

Borm GEL, van den Berg W. 2008. Effects of the application rate and time of the growth regulator trinexapac-ethyl in seed crops of *Lolium perenne* L. in relation to spring nitrogen rate. Field Crops Research. 105:182-192.

This study was conducted in the Netherlands over 4 years on first and second year stands of perennial ryegrass. The effects of different rates and timing of trinexapac-ethyl (Moddus) were explored, as well the effect of greater than normal amount of nitrogen applications (an extra spring application of 45 kg N/ha in addition to the 'normal' amount).

Key findings of the article:

- The optimum crop development stage for the application of Moddus in perennial ryegrass seems to be DC31–33.
- Splitting the rate of Moddus between an early application (DC30–31) and a late application (DC33–37) offered no advantages compared to a single application.
- There was no significant interaction between the application of Moddus and the amount of spring nitrogen.
- Applications at higher rates increased the reduction of stem length, lodging of the crop and the density of panicles.
- Application later than DC30–31 resulted in shorter culm length and higher total dry matter weight of the crop.
- The application of the highest rate of Moddus (1.6 L/ha) at the crop development stage DC30–31 never resulted in an unacceptable final phytotoxic effect
- Effect of Moddus on seed yields was inconsistent (the potential seed yield increase was about 10%)

Find Burak 2006 (Manitoba Forage Seed Association)

Burpee LL. 1998. Effects of plant growth regulators and fungicides on Rhizoctonia blight of tall fescue. Crop Protection. 17(6):503-507.

A field experiment conducted over 1996 and 1997 in which PGRs and fungicides were applied (24 hours apart, not mixed) to tall fescue plots which were then inoculated with *Rhizoctonia solani*, the cause of Rhizoctonia blight. Disease severity was visually assessed. With regards to TE, severity of Rhizoctonia blight was significantly greater

($P<0.05$) on at least one assessment date in each year in plots treated with trinexapacethyl+propiconazole or with any of the PGRs tested +iprodione compared to plots treated with the fungicides alone. However, with the exception of a significant increase in disease in plots treated with paclobutrazol+chlorothalonil late in the 1996 epidemic, the remaining PGR+fungicide treatments had no significant effects on disease severity when compared to the effects of the fungicides alone.

Chastain TG. [Internet]. 2015. Application of the BBCH scale in grass seed crops. Oregon: Oregon State University; [accessed February 25, 2016]. Available from: http://blogs.oregonstate.edu/seedproduction/2015/01/16/application-bbch-scale-grass-seed-crops/.

An easy-to-read breakdown of the BBCH scale. Might be useful in presentations.

Chastain TG. [Internet]. 2014. Plant growth regulators: lodging control agents for grass seed crops. Oregon: Oregon State University; [accessed February 21, 2016]. Available from: http://blogs.oregonstate.edu/seedproduction/2014/04/11/plant-growth-regulators-lodging-control-agents-grass-seed-crops/.

Discusses PGRs, specifically TE (registered as Palisade) and PC (registered as Apogee), as useful lodging control agents for grass seed crops. Notes that currently Apogee is registered for use in Oregon on all grass seed crops grown for seed and that Palisade is registered for perennial ryegrass, tall fescue and fine-leaf fescues.

Chastain TG. [Internet]. 2012. Plant growth regulators and seed weight in perennial grass seed crops. Oregon: Oregon State University; [accessed February 21, 2016]. Available from: http://blogs.oregonstate.edu/seedproduction/2012/08/31/plant-growth-regulators-and-seed-weight-in-perennial-grass-seed-crops/.

A summary of the inconsistencies regarding the effects of PGRs (TE and PC) on seed weight of perennial grass seed crops. Statistically significant effects on seed weight were observed in 7 of the 30 (23%) site years. Five of the significant responses showed that PGRs increased seed weight while the remaining two had PGRs reducing seed weight. Chastain notes that, while there are differences that can be observed in the non-significant data, they are thought to be attributed to chance (evidence of the natural variation in the seed weight characteristic unrelated to the PGR management).

Chastain TG, Anderson NP, Garbacik CJ. 2013. Irrigation and PGR effects on red clover seed production. In Hulting A, Anderson N, Walenta D, Flowers M, editors. 2012 Seed Production Research Report. Oregon State University: Ext/CrS 143.

This study is the first in a series of three. The objective of this study was to quantify the impact of irrigation and its potential interaction with PGR use on red clover seed production under Willamette Valley conditions, performed on two plantings (2011 and 2012). The research looked at irrigation in conjunction with trinexapac-ethyl and prohexamide calcium (note: it appears that the following two studies only looked at TE and irrigation and not PC).

Key findings:

- Irrigation had a significant effect on seed yield, seed weight and other characteristics
- PGR treatments did not significantly increase seed yield in 2012
    - Trinexapac-ethyl treatments reduced seed weight regardless of application rate or timing though greatest reductions were associated with higher application rates and bud emergence timing
    - Trinexapac-ethyl increased the number of seed produced but not enough to offset the reductions in seed weight
    - Prohexamide calcium did not significantly increase seed number but did not reduce seed weight either

- The authors found the results of this study to differ from prior trial results involving trinexapac-ethyl and clover

Chastain TG, Anderson NP, Garbacik CJ, Angsumalee D, Elias SG. 2014. Irrigation and trinexapac-ethyl effects on seed yield in a second-year red clover stand. In Anderson N, Hulting A, Walenta D, Flowers M, editors. 2013 Seed Production Research Report. Oregon State University: Ext/CrS 150.

This is the second year of report on the directly-above mentioned study. The objective of this study was to quantify the impact of irrigation and its potential interaction with PGR use on red clover seed production under Willamette Valley conditions, performed on two plantings (2011 and 2012).

Key findings:

- Irrigation increased yield in both the first and second year stand
- Irrigation increased seed weight in the second year stand
- Trinexapac-ethyl increased seed yield by 10-18% depending on application rate, at application timing of stem elongation, in the second year stand
- Application of trinexapac-ethyl at bud emergence had no effect on yield at the 1 pint/acre rate; Trinexapac-ethyl application [at bud] decreased yield by 8 to 21%, depending on application rate from 2-5 pints/acre
- Inflorescence production tended to be reduced with the application of trinexapac-ethyl at bud emergence which was likely the case of decreased seed yield
- Application at both timings reduced seed weight as rates of trinexapac-ethyl increased. Seed weight was reduced more by applications at bud emergence compared to stem elongation
- Seed number was significantly increased by applications at stem elongation but applications at bud emergence had little effect in this regard

Chastain TG, Garbacik CJ, Young III WC. 2014. Spring-applied nitrogen and trinexapac-ethyl effects on seed yield in perennial ryegrass and tall fescue. Agron J. 106:628-633.

(Taken from the Oregon State university seed blog page, http://blogs.oregonstate.edu/seedproduction)

Key findings of the article:

- Identifies an interaction of spring-applied N and PGR application on seed yield and other seed production characteristics in perennial ryegrass and tall fescue
- Is the first peer-reviewed publication to document the effect of trinexapac-ethyl PGR on increasing seed yield in tall fescue
- Seed yield was only increased in perennial ryegrass and tall fescue by the PGR when recommended rates of applied rates of spring N were made
- Although seed weight was increased by spring N, most of the effect of the combination of spring-applied N and PGR on increasing seed yield was attributable to increases in seed number

Chastain TG, Young III WC, Garbacik CJ, Silberstein TB. 2015. Trinexapac-ethyl rate and application timing effects on seed yield and yield components in tall fescue. Field Crops Research. 173:8-13.

(Taken from the Oregon State university seed blog page, http://blogs.oregonstate.edu/seedproduction)

Key findings of the article:

- Trinexapac-ethyl reduced stem length and controlled lodging in tall fescue across six diverse lodging environments

- Trinexapac-ethyl consistently increased seed yield in tall fescue, but rate of application had no effect on yield.
- Timing of trinexapac-ethyl applications had no effect on seed yield
- Seed yield increases resulting from trinexapac-ethyl were attributable to greater seed number and harvest index
- (Added by S.Kirk from the authors' 'Conclusion' section) For best economic results in controlling lodging and increasing seed yield in tall fescue, trinexapac-ethyl should be applied at a rate no greater than 200 g ai ha−1 and applied at a timing between early stem elongation of the crop (BBCH 32) and early panicle emergence (BBCH 51)

Chastain TG, Young III WC, Silberstein TB, Garbacik CJ. 2014. Performance of trinexapac-ethyl on seed yield of *Lolium perenne* in diverse lodging environments. Field Crops Research. 157:65-70.

(Taken from the Oregon State university seed blog page, http://blogs.oregonstate.edu/seedproduction)

Key findings of the article:

- Application of trinexapac-ethyl PGR reduced stem length and controlled lodging in perennial ryegrass across nine diverse lodging environments in the Willamette Valley of Oregon
- Trinexapac-ethyl PGR consistently increased seed yield and harvest index in perennial ryegrass regardless of the severity of lodging
- Timing trinexapac-ethyl applications between BBCH stages 32 and 51 produced the best seed yield results.
- Seed yield increases resulting from trinexapac-ethyl application were attributable to a greater number of seeds spikelet^{-1}(seed number) and improvements in seed set

Engage Agro. [Internet]. 2015. MANIPULATOR™ 620. Canada: Engage Agro; [accessed March 2, 2016]. Available from: http://www.engageagro.com/Label/59/E/1.pdf.

Container and pamphlet labels outlining the procedures and precautions associated with the use of Manipulator on spring and winter wheat crops, for which it is registered in Canada. It is not registered for use on forage crops as far as I could determine (and which I'm sure you already know).

Fidanza MA, Wetzel III HC, Agnew ML, Kaminski JE. 2006. Evaluation of fungicide and plant growth regulator tank-mix programmes on dollar spot severity of creeping bentgrass. Crop Protection. 25: 1032-1038.

In 2003 and 2004, field studies were conducted to evaluate 14- and 21-day sequential fungicide tank-mix programmes alone and in combinations with plant growth regulators (PGRs) paclobutrazol, trinexapac-ethyl, or paclobutrazol plus trinexapac-ethyl on dollar spot of fairway-height creeping bentgrass.
Key findings:

- All fungicide-treated plots, either fungicides plus PGRs or fungicides alone, exhibited greater dollar spot control versus untreated plots
- Overall, fungicide efficacy on dollar spot was comparable on plots treated with fungicide tank-mix programmes alone versus fungicides plus PGRs
- Creeping bentgrass quality was consistently better in plots treated with fungicides plus PGRs versus fungicides alone
- Dollar spot control and creeping bentgrass quality was improved, however, in plots treated with fungicides plus paclobutrazol versus fungicides alone, fungicides plus trinexapac-ethyl, or fungicides plus paclobutrazol plus trinexapac-ethyl

Gulay, K. [Internet]. 2012. Effects of trinexapac-ethyl on perennial ryegrass in Manitoba. Canada: Manitoba Forage Seed Association; [accessed February 24, 2016]. Available from: http://www.forageseed.net/index.php?option=com_content&view=article&id=172:effects-of-trinexapac-ethyl-on-perennial-ryegrass-in-manitoba&catid=60:2012-research&Itemid=149.

A study done on perennial ryegrass and effects of TE and CCC. Lodging was reduced with the use of CCC and greatly reduced with the use of TE. While a yield reduction was observed with the use of CCC, the use of TE was found to increase the seed yield of perennial ryegrass crops as much as 15%.

Harms CL, Oplinger ES. [Internet]. Date unknown. Plant growth regulators: their use in crop production. USA: North Central Regional Committee; [accessed February 22, 2016]. Available from: http://www.extension.umn.edu/agriculture/nutrient-management/non-traditional-amendments/docs/NCREP-303-1.pdf.

An older extension document discussing the uses of various kinds of growth regulators and the effects on germination, emergence, root growth, nutrients, stress tolerance, moisture, maturity, disease resistance, senescence and yield. Used for some background information.

Kumar B, Singh Y, Ram H, Sarlach RS. 2013. Enhancing seed yield and quality of Egyptian clover (*Trifolium alexandrinum* L.) with foliar application of bio-regulators. Field Crops Research. 146:25-30.

A field experiment was conducted for three years (2008–2011) to investigate the effect of foliar application of five bio-regulators applied at different concentrations, one of these bio-regulators being salicylic acid (a plant hormone involved in many plant physiological processes), on Egyptian clover. Starting at flower initiation stage, three foliar sprays of each bio-regulator were applied at weekly intervals.
Key findings of article:

- Among all the bio-regulators, foliar application of salicylic acid at 50 mg L−1 and KNO3 at 2% recorded the maximum heads m−2, seeds head−1, 1000-seed weight, seed yield and seed quality (germination percentage and seedling vigor index), which were significantly higher than foliar application of the other bio-regulators (except 1% CaCl2) and the control.
- In view of the smaller amounts needed for foliar sprays, salicylic acid is more economical compared with KNO3.

Machač, R. [Internet]. 2010. Effects of trinexapac-ethyl (Moddus) in seed crops of eleven temperate grass species in Central European conditions. In: International herbage seed conference 2010. Proceedings of the Seventh International Herbage Seed Conference; 2010 April 11-13; Dallas, Texas, USA; [accessed February 24, 2016]. Available from: http://ihsg.agriscience.info/subsites/conference2010/documents/IHSC2010PosterProceedings(16).pdf.

[NOTE: This conference article has what appears to be some translation errors. The proper published paper is available as a chapter for purchase in the book "Breeding Strategies For Sustainable Forage and Turf Grass Improvement", Editors Barth, S and Milbourne, D, 2013, but this gives an idea and we can decide to purchase as necessary]

A field experiment was conducted over two years, 2007 and 2008, on the effects of trinexapac-ethyl and eleven grasses including perennial and annual ryegrass, timothy, and meadow and red fescue. In all grass species TE reduced lodging and plant height and increased seed yield (associated with increased number of seeds per panicle). The research involved two types of application, one of TE at growth stage 31-32 and a split application at GS 29 and again at 32. The author noted that the average increase in seed yield was 12-15%. 2007 was a drier year and because of that there was less lodging as well as less of an impact on seed yield by TE.

Meier, U. [Internet]. 2001. Growth stages of mono- and dicotyledenous plants: BBCH monograph. Germany: Federal Biological Research Centre for Agriculture and Forestry; [accessed February 24, 2016]. Available from: http://www.jki.bund.de/fileadmin/dam_uploads/_veroeff/bbch/BBCH-Skala_englisch.pdf.

An in-depth explanation of the growth stages of plants as described by the BBCH. For a specific application of the BBCH growth stages for grass seed plants see the reference from Chastain (2015) from the Oregon State seed production blog.

Pratchler J. [Internet]. 2014. Plant growth regulators (PGRs) in spring wheat. Canada: Northeast Agriculture Research Foundation; [accessed October 27, 2015]. Available from: http://iharf.ca/wp-content/uploads/2015/01/Plant-Growth-Regulators-on-Cereals-Jessica-Pratchler.pdf.

A powerpoint from NARF that discussed chlormequat chloride, ethephon and trinexapac-ethyl in cereal crops in Canada (appears to be based somewhat on the Strydhorst paper but has a few extra bits of information). Also specifically discusses a NARF and IHARF study on PGRs and wheat from 2013 and 2014. Depending on the study they found that applying the PGR at GS 31 or GS 41 produced the best result with regards to plant height reduction and increased yield (due to decreased lodging). They also found that depending on class of wheat (durum, prairie spring and red spring) that yield responses differed (red spring and durum classes had a stronger more consistent response). Also discusses economy of use and whether or not PGR use pays off, specific to these wheat classes.

Silberstein TB, Chastain TG, Young III WC. 1996. Growth and yield of red clover seed crops treated with paclobutrazol and uniconazol. J. Appl. Seed Prod.14:17-23.

May be useful but unable to access this article.

Strydhorst S. [Internet]. 2014. Plant growth regulators: what agronomists need to know. Canada: Alberta Agriculture and Rural Development; [accessed October 27, 2015]. Available from: https://umanitoba.ca/faculties/afs/agronomists_conf/media/MAC_2014_-_Strydhorst_Full_Paper-_Dec_9.pdf.

Overview of PGRs and their use in Canada on cereal crops, particularly of chlormequat chloride, ethephon, and trinexapac-ethyl. This article notes the importance of application timing, and that PGRs may have an adverse effect when used on crops in a stressed situation (dry conditions etc.). It also notes that the main reason to use PGRs in cereal crops is to reduce instances of lodging and therefore improve harvest management.

Syngenta Canada Inc. [Internet]. 2014. PARLAY™. Canada: Syngenta Canada Inc.; [accessed March 2, 2016]. Available from: http://www.syngentacropprotection.com/pdf/labels/parlay_31214_en_pamphlet.pdf.

Pamphlet label outlining the procedures and precautions associated with the use of Parlay on perennial ryegrass (turf only, not forage) crops, for which it is registered in Canada. It is not registered for use on forage crops as far as I could determine (and which I'm sure you already know).

Syngenta Crop Protection Inc. [Internet]. 2013. Palisade® EC. Syngenta Crop Protection Inc.; [accessed February 24, 2016]. Available from: http://blogs.oregonstate.edu/seedproduction/files/2013/05/ORPalisadeECCloverSeedSLNLbl_052313-2.pdf.

Special local need label for use only in Oregon State on red and crimson clover seed grown for seed, non-feed use. From the label: "This pesticide does not have an established pesticide residue tolerance for this crop. Consequently, no portion of this seed crop may be used or distributed for food or feed for 1 year (365 days) after the last application of this product. This restriction pertains to, but is not limited to, green chop, forage, hay, pellets, meal, whole seed, cracked seed, straw, roots, bulbs, foliage or seed screenings, and to the grazing of the

crop field, stubble or regrowth. All seed screenings shall be disposed of in such a manner that the screenings cannot be distributed or used for food or feed purposes…"

Syngenta Crop Protection Inc. 2006. Palisade® EC. USA: Syngenta Crop Protection Inc.; [accessed March 5, 2016]. Available from: http://www.syngentacropprotection.com/pdf/labels/scp949al1d0702.pdf.

For use on perennial ryegrass grown for seed in Oregon, Idaho and Washington only. Restrictions on when animals can be grazed after application (not before 60 days post-harvest). Indications that one can tank mix with specific fungicides.

Zapiola, ML, Chastain TG, Garbacik CJ, Silberstein TB, Young III WC. 2006. Trinexapac-ethyl and open-field burning maximize seed yield in creeping red fescue. Agron. J. 98:1427-1434.

This four year study looked at applications, both fall and early and late spring, of trinexapac-ethyl on two different types of residue management practices (open-burning and mechanical removal [flailing]) for creeping red fescue.

Key findings of the article:

- Spring trinexapac-ethyl applications were promising as a potential alternative to open-field burning during the first 2 years of the trial, but later in the life of the stand, open-field burning became vital, and spring trinexapac-ethyl applications did not increase yield on flail plots.
- Neither spring nor fall applications of trinexapac-ethyl were an effective alternative to replace open-field burning in creeping red fescue seed production over the life of the stand if seed yield is to be maximized
- Spring trinexapac-ethyl applications combined with open-field burning maximized seed yield and had the greatest harvest index
- Trinexapac-ethyl is not effective in fall applications and should be applied in spring if increased seed yield is to be expected; furthermore, this indicates that trinexapac-ethyl does not have residual effect
- No differences were found between early and late spring applications within each residue management treatment in any year, indicating that creeping red fescue has a wide application window for trinexapac-ethyl

Zapiola ML, Chastain TG, Garbacik CJ, Young III WC. 2014. Trinexapac-ethyl and burning effects on seed yield components in strong creeping red fescue. Agron J. 106:1371-1378.

Unable to access this article, see notes below from Oregon State seed blog

(Taken from the Oregon State university seed blog page, http://blogs.oregonstate.edu/seedproduction)

Key findings of the article:

- Fall applications of the PGR had no effect on seed yield components.
- Culm length was reduced and lodging was lessened by spring applications of PGR in strong creeping red fescue.
- Spring applications of PGR increased the number of florets produced.
- A combination of burning and spring PGR applications increased seed number and seed weight, thus contributing to higher seed yields in strong creeping red fescue.

Zhang T, Wang X, Wang Y, Han J, Majerus M. 2009. Plant growth regulator effects on balancing vegetative and reproductive phases in alfalfa seed yield. Agron. J. 101: 1139–1145.

The authors looked at the effect of 5 different PGRs used in combination with chlormequat chloride over three years with the hopes of increasing reproductive capacity of alfalfa (and therefore seed yield) with the former and decreasing plant height with the latter. Chlormequat chloride was applied once per year at the stooling (tillering) stage and the PGRs were applied twice per year at the stages of flower bud formation and at peak flowering. The study took place in northwestern China.

Key findings were:

- All the PGRs used increased the 3-year mean seed yield and harvest index by 10% but did not affect above ground plant biomass
- Chlormequat chloride reduced plant height and the effects of lodging but reduced mean seed yield
- The effects of chlormequat chloride on seed yield depended on climatic conditions
- Neither the PGRs nor the chlormequat chloride affected seed quality
- They conclude that their results suggest that the 5 chosen PGRs could be used to increase seed yield in alfalfa while maintaining high seed quality
- They conclude that their study failed to find the optimum combination of PGR with chlormequat chloride given the variable effects of chlormequat chloride over the three year study