Light, lodging and flag leaves-what drives seed yield in ryegrass?

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Abstract

The effect on seed yield components of reduced photosynthetic capacity of perennial ryegrass (*Lolium perenne* L.) was investigated. Firstly, seed yield responses to plant growth regulators were examined. Lodging during flowering and seed fill had a negative effect on seed yield. Days to 50% lodging is a good predictor of seed yield. Plant growth regulator responses from trinexapac-ethyl rates and timings can be explained by delays in the onset of lodging and improved photosynthetically active radiation (PAR) interception at the mid canopy level. Secondly, following flowering, photosynthetic capacity was reduced by defoliation or shading the flag leaf, stem, or head of individual ryegrass tillers. Reduced PAR to the flag leaf and stem did not affect thousand seed weight or seed yield when compared with control plants whereas reducing PAR to the head had a significant effect. The seed head itself may be a more important source of carbohydrate than the flag leaf during seed fill.

Introduction

Early lodging in perennial ryegrass reduces seed yields (Young et al., 1996). Early lodged crops often trigger secondary vegetative tillering, which may result in nutrient competition with seed fill (Rolston et al. 2007). The plant growth regulator trinexapac-ethyl (TE) inhibits gibberellic acid biosynthesis (Rademacher 2000) and reduces lodging by irreversibly shortening internodes. Seed yield increases in perennial ryegrass (*Lolium perenne* L) from TE rates of 300 to 400 g ha-1 are typically 30 to 50% and the rate response to TE is often linear to rates of 800 g ha^{-1} (Rolston et al. 2004).

Reducing lodging may also increase the amount of photosynthetic radiation within the crop (Rolston et al. 2007). Chemical and mechanical prevention of lodging of perennial ryegrass increased the mobilisation of carbon from the flag leaf to both the reproductive head and the vegetative tillers (Hampton *et al*. 1987). Factors that reduce the amount of photosynthetically active material present on the plant such as lodging or defoliation are likely to influence the amount of carbohydrate that reaches the seed. Competition for photosynthate between plant organs of economic importance and the remaining vegetative structures, that may also support seed fill, is therefore especially important. The aim of this study was firstly to determine seed yield response to TE rate and lodging. Secondly, the importance of the flag leaf, stem, and reproductive head in contributing to seed quality was investigated by reducing photosynthetic active capacity from flowering through to harvest.

Methods

Seed yield response to TE rate

Trials were undertaken in farmers' ryegrass seed production fields in the Canterbury region of New Zealand. There were 6 trials that included four cultivars (Bealey, Commando, Extreme, Hillary, Nui) and four locations (Dunsandel, Lincoln, Methven, Wakanui). All inputs except TE were managed by the grower. Trials had four replicates and plots were 3.2m x 9 m. Each trial consisted of between three and five rates of TE (250 g L^{-1}), with different closing dates or comparing single versus split rates of TE. Lodging was recorded weekly on a 0 (no lodging) to 100% (fully lodged) linear scale from full head emergence Zadoks GS 59 through anthesis and seed fill, and days to 50% lodging was calculated. Components of seed yield were assessed from $0.25m^{-2}$ quadrats cut at late seed fill.

Photosynthetically active radiation (PAR) was measured at the flag leaf level using an AccuPAR LP-80 linear *PAR* Ceptometer (Decagon, Washington) and the percentage of intercepted PAR relative to the upper canopy was calculated.

At harvest a 1.7 m swath was cut from all plots with a modified plot windrower, and then harvested with a plot combine. The crop was windrowed at ca. 40% seed moisture content (SMC) and combined at <14% SMC. Seed samples were machine dressed to achieve a 1st Generation seed purity standard (MAF 2008). Cleaned plot samples were weighed and converted to a yield per ha.

Reduced photosynthetic capacity

Perennial ryegrass (cv. Grasslands Commando) was sown in April 2007 at 7.5 kg ha-1 at the AgResearch Lincoln farm, Canterbury. Plots (9 x 4m) were replicated four times. Spring N was applied in October as urea with two equal applications giving a total of 150 kg ha-1 applied N. The plots were irrigated as required to ensure plants were not under moisture stress.

TE at 1.5 L/ha and Opus fungicide (epoxiconazole 125 g/L) at 0.2 L/ha were mixed and applied as one application on October 24. A tank mix of Amistar (azoxystrobin 250 g/L) at 0.5 L/ha) and Proline (prothioconazole 480g/L) (400 mL/ha) was applied to prevent stem rust. Post anthesis, 30 tillers per replicate had the blade of the flag leaf removed at the collar (treatment 1). A control treatment containing 30 tillers with flag leaf blade attached was also tagged. Stems (20 per replicate) were enclosed in foil below the head (treatment 2) as well as the seed head of additional tillers (20 per replicate) (treatment 3). Five tillers per replicate were also prevented from lodging (treatment 4). Tillers were left to develop through to harvest.

All treatments were hand harvested at approximately 38% SMC. Tillers were air dried, threshed and cleaned to a 1st Generation Seed Certification standard. Seed yield of treatment plots was assessed from $1m^2$ quadrats, and separately for marked tillers (g/tiller). GenStat (v 10) was used for statistical analysis using a general ANOVA model. Samples were designated as treatments and replicates designated as blocks.

Results

The seed yield response to 400 g ha^{-1} TE averaged 720 kg ha^{-1} (42%) from an average of 1720 kg ha^{-1} in the untreated control. The seed yield response is in the range reported by Rolston et al. (2004). With no TE, seed fill occurs when the plant is in a lodged stated compared to the TE 400 rate where plants can complete seed fill in either an erect or semi-erect state. Seed yield increased 22 kg ha^{-1} (1.4%) with each days delay in days to 50% lodging, and the response was linear with an R^2= 0.80 (Fig. 1a).

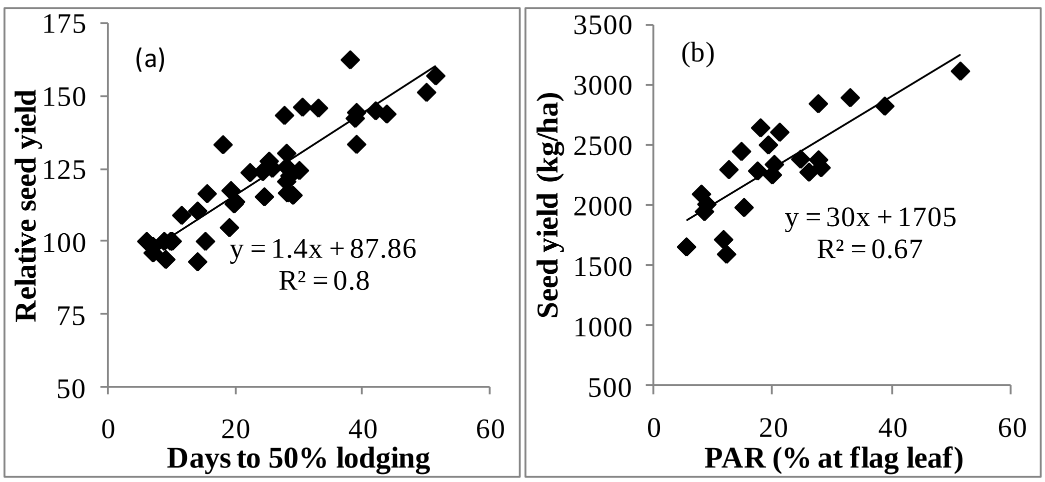

Figure 1. Relative seed yield versus days after flowering to 50% lodging (a) and Seed yield versus percentage of photosynthetically active radiation (PAR) at the flag leaf (b).

There was a strong correlation between light interception at the flag leaf and seed yield. Seed yield increased 30 kg ha^{-1} for every 1% increase in PAR (Fig 1b). Seed yield response in these trials was the result of a higher conversion of fertile florets to saleable seed, resulting in more seeds per unit area. The TE treatment had no effect on seed head density, spikelet numbers per head or florets per spikelet.

Blocking all available PAR to the stem and flag leaf had no effect on TSW when compared to the control treatment (Table 1). No statistical difference was observed between lodged and unlodged tillers. In contrast, reducing PAR to the head during seed fill had a significant effect ($P<0.01$) on TSW (Table 1). This TSW result was reflected in seed yield per tiller, which was also decreased when heads were devoid of PAR during seed fill. A one-tailed t-test confirmed that the treatment with heads shaded was depressed compared with all others ($P<0.01$), equating to an average difference of 470 kg ha-1 of saleable seed. No difference in seed yield was observed when the flag leaf was removed compared to the control treatment.

Table 1. Thousand seed weight (TSW) for all treatments

Treatment	TSW (g)
Stems wrapped	2.95a
Heads wrapped	2.55b
F-leaf removed	3.06a
F-leaf attached	3.10a
Unlodged tiller	3.10a
LSD (5%)	0.28

Discussion

Results of the present study showed a strong correlation between seed yield, lodging and PAR at the mid canopy level. Increased seed yields are often correlated with an increased number of seeds per spikelet (Chynoweth *et al*. 2008). The TE treatment had no effect on seed head density, spikelet numbers per head or florets per spikelet. Early lodged crops often trigger secondary vegetative tillering, which is postulated as either resulting in nutrient competition with seed fill or reducing the level of photosynthetic radiation to the crop (Rolston et al. 2007). Early lodging may also reduce the amount of photosynthetic radiation within the crop.

In the present study, reducing all available PAR to the seed head had a significant effect and decreased average TSW by 16%. Similarly, in a glasshouse experiment, Warringa *et al*. (1998) reported a 10% difference in seed weight when whole tillers of perennial ryegrass were shaded by 75%. These results suggest that shading induced by lodging may have a negative effect on perennial ryegrass seed yields through reduced light interception of the seed head itself.

Conclusion

The plant growth regulator TE increases ryegrass seed yields by delaying the onset of lodging and increasing light interception at the mid canopy. The number of days from full head emergence to when the crop is 50% lodged is highly correlated with seed yield. Seed growers are recommended to use rates of TE to achieve a crop that is ≤ 50% lodged at harvest. Furthermore, head photosynthesis contributes explicitly to seed fill. The reproductive head itself may be more important than the flag leaf in contributing to seed weight and determining tiller seed yield.

Acknowledgement

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References

Chynoweth, R.J.; Rolston, M.P.; McCloy, B.L. 2008. Plant growth regulators: a success story in perennial ryegrass seed crops. *Seeds for Futures. Agronomy Society of New Zealand Special Publication X/Grassland Research and Practice Series*

Hampton, J.G.; Clemence, T.G.A.; Hebblethwaite, P.D. 1987. The effect of lodging on ^{14}C-assimilate distribution after anthesis in *Lolium perenne*, cv. S24, grown for seed. *Grass and Forage Science 42*: 121-127.

MAF 2008 Seed Certification 2007-2008 Field & Laboratory Standards. AsureQuality, MAF Plants Biosecurity and New Zealand Seed Quality Management Authority. 77p.

Rolston, M.P; McCloy, B.L.; Pyke, N.B. 2004 Grass seed yields increased with plant growth regulators and fungicides. *Proceedings of the New Zealand Grassland Association 66*:127-132.

Rolston, P.; Trethewey, J.; McCloy, B.; Chynoweth, R. 2007. Achieving forage ryegrass seed yields of 3000 kg/ha and limitations to higher yields. 6th International Herbage Seed Conference, Norway: 100-106.

Warringa, J.W.; Struik, P.C.; de Visser, R.; Kreuzer, A.D.H. 1998. The pattern of flowering, seed set, seed growth and ripening along the ear of *Lolium perenne*. *Australian Journal of Plant Physiology 25*: 213-223

Young, W.C. Chilcote, D.O. Youngberg, H.W. 1996. Seed yield response of perennial ryegrass to low rates of paclobutrazol. *Agronomy Journal 88*: 951-955

Zadoks, J.C. Chang, T.T. Konzak, C.F. 1974. A decimal code for the growth stages of cereals", *Weed Research 14*:415-421.