The impact of different post-harvest residue management practices on a tall fescue (*Festuca arundinacea*) seed crop with full straw load retained

L. Jones[1], R.E. Sim[2], J.G. Hampton[1], M.P Rolston[3] and M. Kelly[2]

[1] Seed Research Centre, Lincoln University, Canterbury, New Zealand

[2] Kimihia Research Centre, PGG Wrightson Seeds Ltd., Canterbury, New Zealand

[3] Foundation for Arable Research (FAR), Templeton, Canterbury, New Zealand

lauren.jones@lincolnuni.ac.nz

Abstract

A variety of post-harvest residue management practices are used for tall fescue (*Festuca arundinacea*) seed crops in New Zealand. Previously farmers relied on methods such as burning residue but due to a change in social license around air quality and public safety concerns there has been a reduction in this management practice. As a result alternative methods are required. The objective of this research project was to refine the non-thermal post-harvest residue management practices required to maximise seed yield for a tall fescue seed crop with full post-harvest straw load retained. Two experiments were conducted on a crop of tall fescue (cv. Volupta) entering its third year of seed production. Trial 1 showed that the most effective method of residue management was to leave the crop stubble at a post-harvest height of 14 cm, and to mow the crop either under a frequent or lax regime. The frequency of the mowing treatments had no effect on seed yield. These treatments produced an average seed yield of 435 kg/ha. Trial 2 showed that under grazing, seed yields were highest in the plots with 14 cm of stubble after harvest with an average seed yield of 327 kg/ha. Spring nitrogen applications in the grazed trial had no effect on final seed yield.

Additional keywords: seed production, tiller production, grazing, nitrogen, cutting

Introduction

New Zealand's herbage seed industry produces around 40,000 t annually (Robertson and Hurren, 2019). 85% of which is from perennial ryegrass (*Lolium perenne* L.), Italian ryegrass (*Lolium multiflorum* L.), and tall fescue (*Festuca arundinacea* Schreb.). Tall fescue, a perennial grass with pasture and turf varieties is typically grown in New Zealand for animal forage. It is also grown in high quantities in Oregon for the turf market (Liang, 2012). In recent times tall fescue has increased in popularity as a resilient pasture plant. This is due to its wider tolerance for environmental extremes that the more commonly sown perennial ryegrass (*Lolium perenne*) struggles to persist through (Mohlenbrock, 2002).

Tall fescue seed crops are established in wide rows (30-60 cm) due to the dense structure of the plant (Chastain et al., 2000). Sowing date is highly influential in determining final seed yield in first year crops. Hare (1994) found that when the sowing date in New Zealand is moved from 4 March to 15 April there was a 69% decline in the number of seeds per m^2. This was because autumn tiller production is required to allow for vernalisation to occur over winter (Hare, 1994). Typically sowing rates of 20 kg/ha or below are recommended as tall fescue seed crops become very dense (Hickey, 1990), therefore reducing light penetration to the crown.

Perennial seed crops such as tall fescue require different post-harvest management compared to annual seed crops due to the residue or "trash" as it is sometimes referred to which needs to be removed from the system. This allows the crop underneath to recover and produce seed for the following year. Post-harvest management of perennial seed crops is important for reproductive tiller formation (Hare, 1993). This tiller formation can seriously be inhibited when the residue is not managed correctly which will reduce seed yield (Hare, 1993). Oregon growers had relied on burning methods since the 1940s to remove the trash (Hare, 1998). Over time this management practice has changed as laws that encompass air quality and public safety concerns now prevent the burning of crops. As a result more research is required looking into alternative residue non-thermal management practices for residue removal.

The objective of this research was to better understand the non-thermal post-harvest residue management practices of a tall fescue seed crop with full straw load retained after seed harvest.

Materials and Methods

Experimental site

The experiment was conducted at Barrhill, Methven in paddock 10 (43° 41'S, 171° 54' E). The paddock of tall of tall fescue (cv. Volupta) was sown in March 2018 and was in its third year of seed production. The trial began on 23 January 2020 and seed was harvested on 12 January 2021. Volupta is a perennial French cultivar used for forage, being grown in New Zealand for a multiplication for export back to Europe.

Experimental design

The trial site was split into two split plot design trials which ran alongside each other. Both trials had full straw load retained on the plots after the seed harvest in January 2020. There was an average of 1500 kg DM/ha returned to the crop. On plots cut to 7 cm the standing residual was 2400 kg DM/ha. In plots left at 14 cm the standing residual was on average 3200 kg DM/ha. Both trials had four replicates per treatment.

Trial 1 was a grazing exclusion trial with flexinet fencing used to keep stock out. The main plots (12 x 25 m) were cut to two post-harvest residual heights, either; *i*) conventional, the crop stubble left at the harvest mowing height of 14 cm, or *ii*) mown, stubble cut post-harvest using a disc mower to 7 cm. The sub-plots (12 x 4 m) consisted of three mowing frequency managements; *i*) nil, *ii*) lax, where plots were cut once at the end of May, and *iii)* frequently, where plots were mowed monthly to either 7 or 14 cm (Table 1).

Trial 2 was a grazing trial that involved using stock to manage the residue. Calves and store lambs were set stocked from after harvest until closing of the new seed crop (30 January 2020 to 12 June 2020). The main plots (12 x 25 m) were cut to two post-harvest residual heights, either; *i*) conventional, the crop stubble left at the harvest mowing height of 14 cm, or *ii*) mown, stubble cut post-harvest using a disc mower to 7 cm. Sub plots (12 x 4 m) consisted of an additional 50 kg N/ha at *i)* early during August *ii)* standard practice during September or *iii)* late timing during October (Table 1).

Table 1: Treatment list and the assigned acronyms.

Trial 1	Mowing Height	Cutting Frequency	Acronym	Symbol
	Short[1]	Frequent[3]	SF	●
	Short	Lax[4]	SL	○
	Short	Nil	SN	▼
	Tall[2]	Frequent[3]	TF	△
	Tall	Lax[4]	TL	■
	Tall	nil	TN	□
Trial 2	**Mowing Height**	**Fertiliser Timing**	**Acronym**	**Symbol**
	Short[1]	Early[5]	SE	●
	Short	Late[6]	SLA	○
	Short	Standard Practice[7]	SSP	▼
	Tall[2]	Early[5]	TE	△
	Tall	Late[6]	TLA	■
	Tall	Standard Practice[7]	TSP	□

[1]Short = 70 mm, [2]Tall = 140 mm, [3]Frequent = monthly, [4]Lax = Once in June, [5]50 kg N/ha in August, [6]50 kg N/ha in October, [7]50 kg N/ha in September.

Agronomic management

The crop was originally sown at a sowing rate of 30 kg/ha in 30 cm row spacings. Soil tests showed that prior to starting this trial there were no nutrient deficiencies. The herbicide Atraflo (a.i. Atrazine 500 g/l) was applied at a rate of 600 ml/ha. Mixed in with this was Karmex (a.i. Diuron: 3-(3,4-dichlorophenyl)-1.1-dimethylurea (80%)) applied at a rate of 1.25 kg/ha. This combination was applied on 22 May. The air temperature of the crop was at less than 10˚C for 1612 hours over the autumn and winter period. For vernalisation to occur temperatures needed to be less than 10˚C for 1440 hours (Hare, 1992).

The crop had 190 mm of irrigation applied from January 2020 to January 2021, and there was 661 mm of rainfall.

Climate data (Figure 1) (temperature and humidity) were recorded throughout the trial using a HOBO MX2301A datalogger weather station with a MX2300 Large Solar Radiation shield. The was under a centre pivot irrigator alongside the rest of the paddock as part of a rotational system.

Measurements and calculations

Soil samples were taken to a depth of 150 mm using a soil corer on 5 February 2020 to assess autumn fertiliser application requirements. Samples were taken at random throughout the trial area and then bulked to a 500 g sample.

Quadrat cuts were taken on average monthly until closing and then once again prior to seed harvest. Samples were taken from a 0.5 m^2 quadrat and 150 g subsamples were then dried at 90˚C for 48 hours for dry weights. Tiller counts were taken during autumn and prior to harvest. Tillers were counted from a 10 x 20 cm wedge that was removed from the drill row. Light interception readings were carried out on average monthly until canopy closure (2

November). These were taken using an AccuPAR ceptometer, model LP-80 diagonally across the rows in each subplot. The fraction of intercepted light was calculated as the above plot light divided by the below canopy radiation.

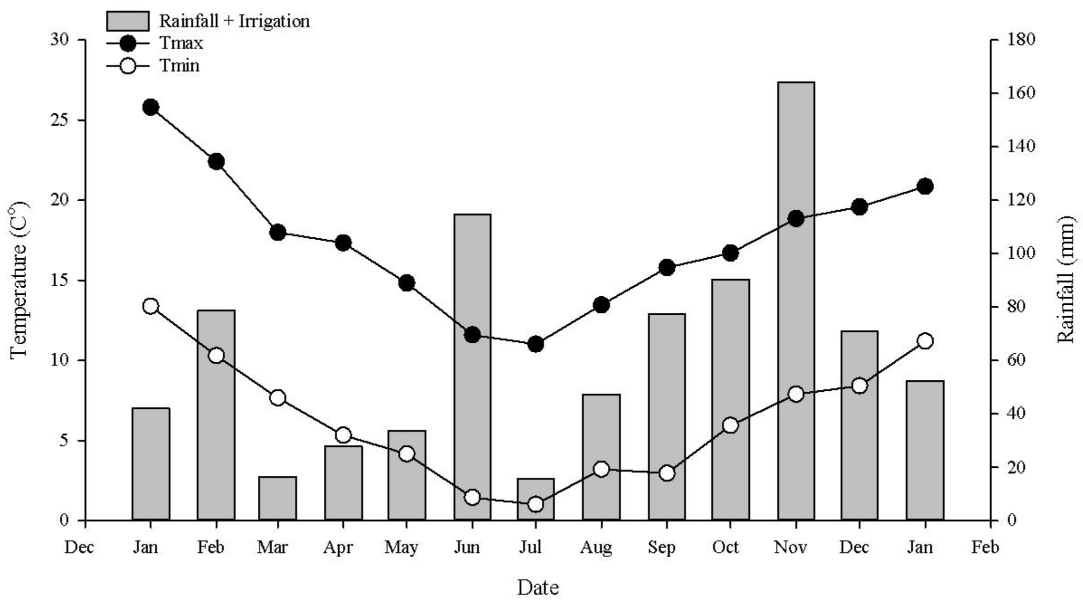

Figure 1: Climate data from January 23 2020 to 12 January 2021. Maximum and minimum temperatures were recorded throughout the trial using a HOBO MX2301A datalogger weather station with a MX2300 Large Solar Radiation shield. Rainfall was calculated from NIWA's CliFlo database and irrigation was added to this.

Seed was harvested on 12 January 2021. Harvest date was determined from seed moisture content readings obtained using a Sartorius moisture analyser (model MA160). The trial was windrowed at a seed moisture content of 46% on 29 December using a Wintersteiger windrower. Seed was then harvested at a seed moisture content of 15% using a specialised KW Engineering plot harvester, dried to a moisture content of 10% and dressed using a conventional small seed cleaner.

The results were analysed using the statistical analysis programme GenStat 19th edition. The statistical analysis carried out on each of the datasets was a split-plot analysis of variance (ANOVA). To ensure the requirements of an ANOVA were met each dataset will be tested for homogeneity and normality. The fishers protected LSD post-hoc test was used to determine differences between variables.

Results

Seed yield

The highest seed yields were from the mowed to 14 cm after harvest and frequently mown (TF) or lax mown (TL) treatments. The seed yields for these two treatments averaged 435 kg/ha. For the ungrazed trial (Trial 1) mowing plots to 7 cm after harvest caused a 40% reduction in final seed yield compared with when plots were left at the original height of 14 cm ($P < 0.01$) (Table 2). When plots were not mown at all following the cutting treatments after harvest there was a 53% decline in yield compared with treatments that were mown frequently or lax.

For the grazed trial (Trial 2) the plots mown to 7 cm had a 22%lower seed yield than the plots mown to 14 cm (P = 0.004) (Table 2).

There were no differences in seed yield among any of the spring nitrogen timing treatments (P > 0.05).

Table 2: Vegetative tiller counts (number of tillers m^2) sampled on 6 July and 24 December, reproductive tiller counts (number of tillers m^2) samples on 24 December and final seed yield (kg/ha) weighed at a moisture content of 10%. Letters indicate significant differences.

		Vegetative Tillers		**Reproductive Tillers**	**Seed Yield**
	Treatment	**July**	**December**	**December**	**January**
Trial 1	**SF**	5991 a	9141 a	120 b	262 c
	SL	5408 a	6316 a	115 b	252 c
	SN	3733 a	4050 a	81 bc	140 d
	Mean	**5044 a**	**6502 a**	**105 b**	**218 c**
	TF	3933 a	7566 a	229 a	421 ab
	TL	3016 a	5983 a	226 a	451 a
	TN	2183 a	3183 a	130 b	225 c
	Mean	**3044 a**	**5577 a**	**195 a**	**365 b**
	S.E.M.	257.7	182.2	14.88	23.1
	P value	0.706	0.813	< 0.001	< 0.001
Trial 2	**SE**	10362 a	7849 a	151 ab	253 b
	SLA	6632 a	7174 a	155 ab	238 b
	SSP	8332 a	9740 a	117 b	268 ab
	Mean	**8442 a**	**8254 a**	**141 b**	**253 b**
	TE	5399 b	8232 a	191 ab	318 ab
	TLA	5632 b	6949 a	205 ab	317 ab
	TSP	6332 b	6849 a	230 a	346 a
	Mean	**5787 b**	**7343 a**	**208 ab**	**327 ab**
	S.E.M.	421.2	827.1	38.5	27.2
	P value	0.048	0.950	0.034	0.040

Fraction of light intercepted

In Trial 1 at the January sampling date the highest fraction of light interception was in the plots left at 14 cm after the initial harvest with an average (TF, TL, and TN) of 86% light interception (P < 0.001) (Figure 2). The mowing frequency treatments were imposed in mid-February therefore there were no significant differences among subplots at the January or February measurements (P > 0.05). At the June sampling date the short mowing treatments had 8% lower fraction of light intercepted compared with the lax and nil cut treatments (P < 0.001). There were no differences between mowing heights at this sampling time (P = 0.096). At the August sampling date there were no differences between mowing heights (P = 0.097). The frequent mowing treatment had the lowest light interception at 91% compared with the lax and nil treatments that had an average light interception of 98% (P < 0.001). At the November sampling date the TF and SF treatments had the lowest light interception averaging 90% (P < 0.001). The TN and SN treatments had the highest light interception with 98% light interception (P < 0.001).

In Trial 2 at the January and February sampling dates there were no differences in light interception (P = 0.76). At the June sampling dates the fraction of light intercepted was 21% higher in plots left at 14 cm (P = 0.007) compared to plots cut to 7 cm. At the August sampling date light interception was 12% higher in plots left at 14 cm compared to plots mown to 7 cm (P = 0.011). At the November sampling date there were no differences (P = 0.707). The additional nitrogen application timings had no impact on the resulting fraction of light interception at any of the sampling dates (P > 0.05).

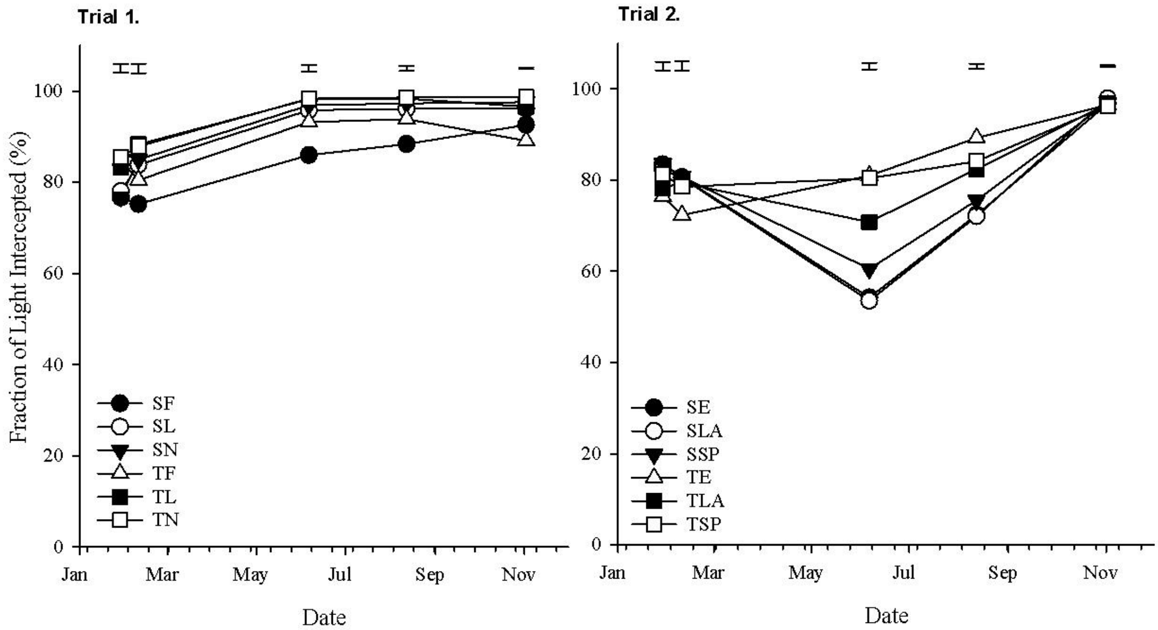

Figure 2: Fraction of light intercepted by the canopy for Trial 1 And Trial 2 sampled on 29 January, 10 February, 6 June, 12 August and 2 November. Error bars indicate standard error of means.

Biomass cuts

In Trial 1 there was a mean increase of 403 kg DM/ha biomass on the plots mown to 14 cm compared with the mean biomass of plots mown to 7 cm after seed harvest (Figure 3). In February the biomass of the plots mown to 7 cm was 1451 kg DM/ha less than biomass on the plots left at 14 cm (P < 0.005).

At the May biomass cut the tall nil cut (TN) treatment produced the highest biomass (Figure 3) at 5313 kg DM/ha. This was 36% more biomass than the TF and SN treatments (P < 0.001). The lowest amount of biomass was produced in the plots with the SF treatment (1437 kg DM/ha). This was 73% lower than the TN treatment (P < 0.001). At the June biomass cuts the TN treatments produced 47% more kg DM/ha than the other treatments (P < 0.001).

In Trial 2 for the first biomass cut in January there were no differences among treatments (P > 0.05). The February biomass was 69% higher in the plots left to the 14 cm height than on the plots mown to 7 cm (P = 0.002). At the May biomass cuts there was 1601 kg DM/ha more on the plots left to the 14 cm height than on the plots mown to 7 cm (P = 0.01). In June there was 1800 kg DM/ha more on the 14 cm plots than the mown to 7 cm plots (P = 0.01). There were no differences in biomass among fertiliser timing treatments.

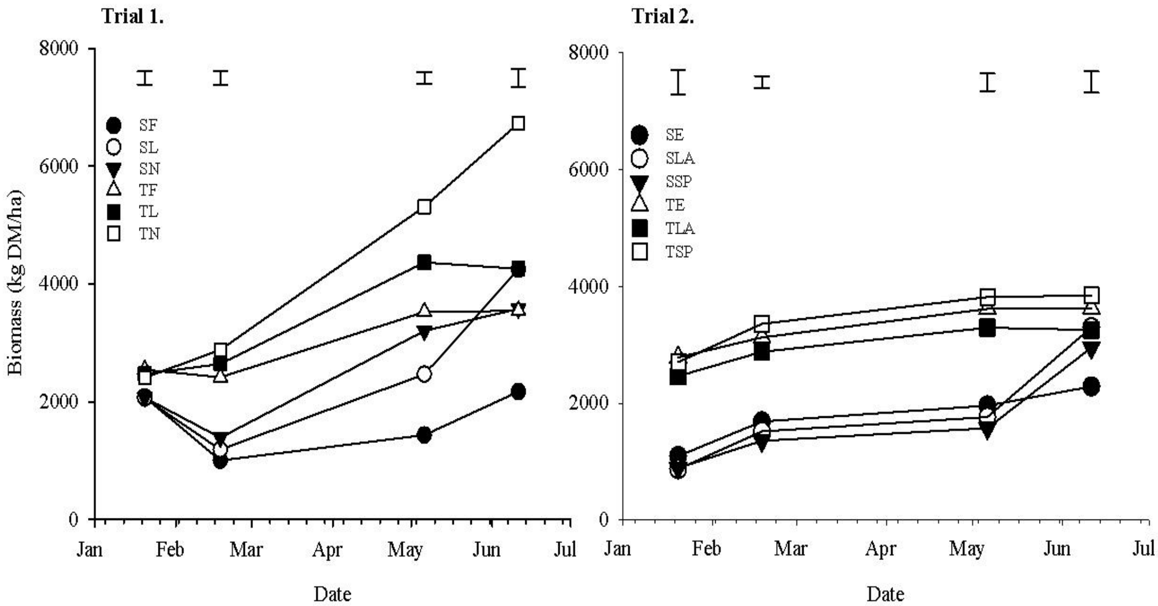

Figure 3: Biomass (kg DM/ha) sampled from Trial 1 and Trial 2 on 20 January, 18 February, 6 May. Error bars indicate standard error of means.

Tiller counts

In Trial 1 there were no differences (P > 0.05) in vegetative tillers at the July or December sampling dates among the cutting frequency or mowing height treatments (Table 2). At the December sampling date there were on average 48% more reproductive tillers per m^2 in the plots left at the original height of 14 cm than in the plots mown to 7 cm (P = 0.003). The treatments with the highest reproductive tiller number per m^2 were the TF and TL treatments (P < 0.001). The SF, SL and SN treatments had on average 53% less reproductive tillers than the TF and TL treatments (P = 0.001) but did not differ from the TN treatment (Table 2).

In Trial 2 there were 32% more vegetative tillers (P = 0.05) in the plots cut to 7 cm than the plots left at the harvest height of 14 cm at the July sampling date (Table 2). There were no differences between the number of vegetative tillers per m^2 for any of the treatments (P > 0.05) at the December sampling date. At the December reproductive tiller counts there were 32% more reproductive tillers per m^2 in the plots left at the harvest height of 14 cm (P = 0.03). There were no differences in number of reproductive tillers per m^2 for any of the fertiliser treatments.

Regression of seed yield and tiller number

Using data from both trials there was a positive linear regression (R^2 = 0.8) between final seed yield (kg/ha) and Reproductive tiller number (tillers per m^2) (Figure 4).

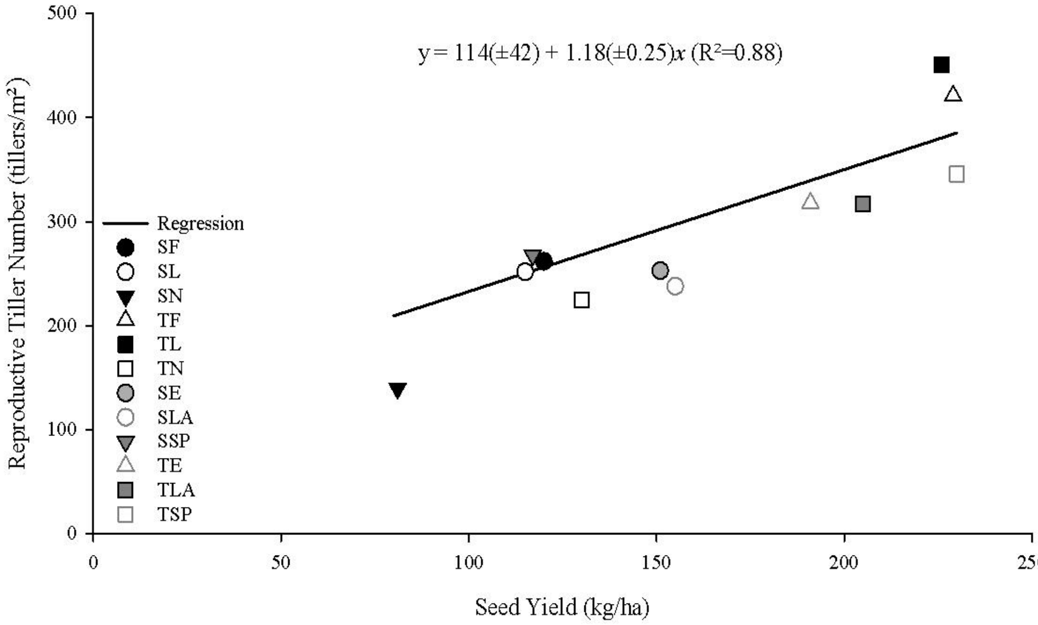

Figure 4: Regression of seed yield (kg/ha) at a moisture content of 10% vs reproductive tiller number (tillers per m^2).

Discussion

Under a cutting regime the residue management practice of leaving the crop residue at 14 cm after seed harvest produced on average a 40% higher seed yields than the plots mown to 7 cm. This went against initial expectation that cutting lower into the sward would allow more light into the base of the canopy and encourage tiller production to increase final seed yield. The initial hypothesis presumed under short canopies there was a higher rate of light available for interception at the crown and therefore more tillers would be produced. Under a grazing post-harvest residue management final seed yield was on average 23% higher in plots left at 14 cm compared with plots mown to 7 cm after harvest.

In Trial 1 there were no differences in number of vegetative tillers at the July or December sampling dates under the cutting frequency or mowing height treatments. This was likely due to swards from both mowing heights maintaining a relatively complete canopy throughout the vegetative stages (Jones, 2013). The fraction of light intercepted was not different at the two mowing heights ($P > 0.05$) at the June and August dates. Over the winter period the fraction of light intercepted was lowest in the frequent cut treatment at 91% compared with the average light interception of the lax and nil treatments at 97%. In November the highest light interception measurement was 98% in the TN treatment and the lowest was in the TF treatment with 89%. This suggests that the 9% difference in light interception was not significant enough to have an impact on vegetative tiller number. In Trial 1 biomass was significantly higher in the plots left at the initial post-harvest height of 14 cm at the May and June sampling dates. The July tiller counts did not show any differences so this suggests that most of the biomass was leaf tissue rather than tillers. The length of new leaves and their rate of appearance is strongly influenced by the length of the leaf sheath below (Jones, 2013). In Trial 1 biomass was highest in the nil cut plots left at 14 cm. This treatment had a 53% lower seed yield than plots mown. This was likely a result of shading of the crown. Hare (1992) found that when tillers are exposed to shaded conditions new tillers either fail to initiate, or reproductive fertility 50% less.

Reproductive tiller numbers in the plots left at 14 cm after harvest were higher than in plots mowed to 7 cm ($P = 0.003$) (Figure 2). There is a direct positive correlation ($R^2 = 0.8$) observed between fertile tiller number and final seed yield. A similar relationship to that reported by (Heineck *et al.*, 2020). This suggests that light interception was not the main discerning factor affecting the final seed yield. It is possible that differences in carbohydrate stem reserves among the treatments could explain the seed yields. Nofal *et al.* (2004) found that in cool season grasses there was a direct correlation between intensity of defoliation and non-structural carbohydrate stem reserves in the tillers. Brougham (1957) found that crops defoliated to 12.5 cm only took 4 days to regain full light interception and therefore replenish carbohydrate reserves whereas crops defoliated below 7.5 cm took up to 24 days. Under reproductive signalling, the consequential meristematic activity consumes 40-50% of the total available carbohydrates. As the crops mowed to 7 cm were defoliated every 30 days this suggests that carbohydrate reserves were consistently being depleted in the SE plots resulting in the lower number of reproductive seed heads and subsequent seed yield.

Under grazing the number of vegetative tillers was higher in the plots mown to 7 cm than in the plots left at 14 cm. This suggests that there was higher level of incident radiation available for interception at the crown. This is reinforced with the highest level of light getting through the canopy in plots mown to 7 cm. Williamson *et al.* (2012) found that an increase in the red-far/red light ratio caused a 25% increase in the number of buds resulting in tillers in a variety of C_3 grasses. Under grazing biomass stayed relatively consistent and did not increase over time. The plots left at the height of 14 cm had significantly higher biomass. As biomass was not changing this suggests that the plots mown to 7 cm were consistently being grazed to their residual height. Reproductive tiller number per m^2 was 32% higher in the plots left at 14 cm compared with the plots mown to 7 cm. This result reinforces the results from Trial 1 in that potentially the smaller tillers lack the carbohydrate reserves to become reproductive.

A study by Volenec (1986) showed a 50% decline in stem carbohydrate reserves 4 days after a defoliation event while the plant recovered. After 24 days total non-structural carbohydrates within the stem reach 93% of their initial levels. This suggests that under a set-stocked system the crop was unable to replenish non-structural carbohydrates as there were insufficient “rest periods” between defoliations. For the plots mowed to 7 cm there were insufficient photosynthetic tissues to generate carbohydrates to replenish reserves.

The additional nitrogen timing treatments had no impact on any measurements taken for the components of seed yield. This was likely due to a “ceiling” being reached in the amount of nitrogen present within the system. Meijer and Vreeke (1988) found that when applying nitrogen fertiliser at an application rate of 180 kg N/ha there was no increase in seed yield compared with a 150 kg N/ha. At an application of 210 kg N/ha there was a decline in seed yield of 40 kg/ha. Trial 2 had 197 kg N/ha applied to the plots in Autumn. This suggests that the trial already had sufficient nitrogen prior to the additional nitrogen applications of 50 kg

N/ha which explains why there was no significant effect on the final seed yield. Anderson *et al*. (2014) recommends a 100 kg N/ha application of spring nitrogen and a 50 kg N/ha autumn fertiliser application.

Recommendations and Conclusion

Based on the final seed yield in Trial 1 it can be recommended that the best agronomic practice would be to leave the post-harvest stubble at the height of 14 cm. This height had the highest reproductive tiller number and therefore highest overall seed yield in the succeeding crop. The frequent and lax mowing treatments did not produce seed yields that were different from each other. This suggests that growers could take multiple or single bailage/hay cuts and there would be no impact on seed yield. In Trial 2. there were no differences among any of the additional nitrogen timing treatments, and therefore it can be recommended to growers that there will be no impact on seed yield from applying spring nitrogen if there are no nitrogen deficiencies in the crop. Leaving plots at the 14 cm height under grazing also produced the highest seed yields. Future research could investigate the impact that stem carbohydrate reserves have on tall fescue final seed yield as much of the current research is carried out in perennial ryegrass. Research on this topic is limited for tall fescue and the results would likely be cultivar specific. Future research could also investigate the lowest transmitted light available at the crown that will still allow reproductive tillers to be produced.

This study has demonstrated the importance of post-harvest residue management. Without any management of residue there was a decline in final seed yield. The cutting frequency did not have an effect on the final seed yield which suggests that multiple hay/bailage cuts can be taken from a crop diversifying the income. Under a grazing system the height the crop was left at after harvest was just as influential on final seed yield. The highest seed yields were in plots left at 14 cm. At this site spring nitrogen applications did not increase seed yield of the crop.

Acknowledgements

Lauren Jones would like to thank the Seed Industry Research Centre (SIRC) for funding this project and PGG Wrightson Seeds Ltd. for the use of their equipment and facilities. She would also like to thank Simon Lochhead for the use of his crop and property. Lauren Jones would like to acknowledge R.J Chynoweth for his advice throughout the planning of this trial, and S.R Hunter for his support and help with trial work.

References

Anderson, N.P., Chastain, T.G., Hart, J.M., Young, W.C. and Christensen, N.W. 2014. Tall fescue grown for seed: A nutrient management guide for western Oregon. *Oregon State University*.

Brougham, R. 1957. Some factors that influence the rate of growth of pasture. *Proceedings of the New Zealand Grassland Association* 19: 109-116.

Chastain, T.G., Young III, W.C., Garbacik, C.J., Meints, P.D. and Silberstein, T.B. 2000. Alternative residue management and stand age effects on seed quality in cool-season perennial grasses. *Seed Technology*, 34-42.

Hare, M.D. 1992. Seed production in tall fescue (*Festuca arundinacea* Schreb.): a thesis presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Seed Technology at Massey University, Palmerston North, New Zealand.

Hare, M.D. 1993. Post-harvest and autumn management of tall fescue seed fields. *New Zealand Journal of Agricultural Research* 36: 407-418.

Hare, M.D. 1994. Autumn establishment of three New Zealand cultivars of tall fescue (Festuca arundinacea Schreb.) for seed production. *New Zealand Journal of Agricultural Research* 37: 11-17.

Hare, M.D. 1998. Establishment, spacing density and grazing effect. *NZGA: Research and Practice Series* 5: 9-19.

Heineck, G.C., Ehlke, N.J., Altendorf, K.R., Denison, R.F., Jungers, J.M., Lamb, E.G. and Watkins, E. 2020. Relationships and influence of yield components on spaced-plant and sward seed yield in perennial ryegrass. *Grass and Forage Science* 75: 424-437.

Hickey, M. 1990. Seed production of “Grasslands Roa” tall fescue in Southland. *Proceedings of the New Zealand Grassland Association* 52: 111-113.

Jones, M. 2013. "The grass crop: the physiological basis of production," Springer Science & Business Media.

Liang, X.L. and Wang, J. 2012. Chapter 16 - Vegetation Production in Terrestrial Ecosystems. *In* "Advanced Remote Sensing" (S. Liang, X. Li and J. Wang, eds.), pp. 501-531. Academic Press, Boston.

Meijer, W. and Vreeke, S. 1988. Nitrogen fertilization of grass seed crops as related to soil mineral nutrition. *NJAS Wageningen Journal of Life Sciences* 36: 375-385.

Mohlenbrock, R.H. 2002. TALL FESCUE Lolium arundinaceum. *USDA NRCS*, 202-207.

Nofal, H.R., Sosebee, R.E., Wan, C., Borrelli, J., Zartman, R. and McKenney, C. 2004. Mowing rights-of-way affects carbohydrate reserves and tiller development. *Rangeland Ecology and Management* 57: 497-502.

Robertson N, and Hurren, K. 2019. Arable Production 2018, Economic Impact Assessment. *In* "Hōngongoi 2019".

Volenec, J. 1986. Nonstructural carbohydrates in stem base components of tall fescue during regrowth. *Crop Science* 26: 122-127.

Williamson, M.M., Wilson, G.W. and Hartnett, D.C. 2012. Controls on bud activation and tiller initiation in C3 and C4 tallgrass prairie grasses: the role of light and nitrogen. *Botany* 90: 1221-1228.