Herbage and vegetable seed reports

Contents

Red beet seed crop tolerance to herbicides used for mallow control

Project code B19-01

Duration Year 3 of 3

Authors Phil Rolston, Matilda Gunnarsson, Richard Chynoweth, Owen Gibson, Fiona Anderson (FAR)

Location Irwell, Mid-Canterbury (GPS: 43° 41’ 12.40” S; 172° 19’ 59.24” E); Dunsandel, Mid-Canterbury (GPS: 43° 37'15.3" S, 172° 06'32.3" E)

Funding Seed Industry Research Centre (SIRC)

Acknowledgements Glenn Smith and John Michael (trial hosts); NZ Arable (trial operators); James Taylor (South Pacific Seeds)

Key points

- No significant effects of herbicide treatment or timing of application on seed yield.
- The Group 14 herbicide, carfentrazone-ethyl (Hammer® Force) caused severe leaf burn (30-50%) when applied to red chard crops in May or early June, but damage was less severe when applied in late-June, July, August or September.
- Crops treated earlier in the season recovered, providing they were not sprayed a second time later in the season.
- Stomp® Xtra (a.i. 455 g/L pendimethalin, Group 3) at 2.5 L/ha produced more leaf damage in both female and male plants than Hammer® Force alone or Hammer® Force with Goltix® (a.i. 700 g/kg metamitron, Group 5) and Nortron® (a.i. 500g/L ethofumesate, Group 15) added.

Background

A number of weed species, including mallows, cleavers and field pansy, are difficult to control in vegetable beet/chard seed production. There are two common mallow species: large-flowered mallow (*Malva sylvestris*) with purple flowers, and small-flowered mallow (*Malva parviflora*) with smaller whitish flowers. Mallows are a competitive weed when populations are high and also a seed-dressing weed, as their seeds are very difficult to remove from beet seed during seed cleaning.

This trial investigated crop damage from multiple application timings of the Mode of Action Group 14 herbicide Hammer® Force.

The Mode of Action Group 14 herbicide Hammer® Force (active ingredient (a.i.) carfentrazone-ethyl) has been used to control members of the Malvaceae family such as velvet leaf (*Abutilon theophrastia*). In New Zealand, Hammer® Force is registered as an additive for herbicides used in wheat, barley and grass seed crops as well as a desiccant for aiding potato harvest. A preliminary trial in 2018 identified that the Hammer® Force has potential for the management of mallow in beets, with up to 83% control. Further work in 2018-19 found that when applied in mid-May, Hammer® Force caused severe leaf burn that resulted in a 13% seed yield reduction compared with the untreated control. Later application timings in June, July or August reduced ($p<0.001$) herbage damage and maintained seed yield (Chynoweth and Rolston 2019). Product guidelines indicated that Goltix® (a.i. 700 g/kg metamitron), Nortron® (a.i. 500g/L ethofumesate) and Stomp® Xtra (a.i. 455 g/L pendimethalin) could be used in conjunction with Hammer® Force to broaden the weed spectrum, hasten knockdown and improve control of hardier weeds, such as mallows.

The initial and subsequent trial observations confirmed that the timing of Hammer® Force application can be important. Herbicide-induced symptoms may be accelerated when using this herbicide in warm moist conditions. Under dry and cold conditions, the expression of herbicide damage is slower. These effects are particularly prominent in autumn with plants more susceptible to leaf burn.

Methods

Trial 1 was located in a commercial hybrid red chard seed field near Irwell, Canterbury (elevation 30 m asl). The soil type was a Mayfield f-1 silt loam. The crop was sown on 29 February 2020 with beds of 16 female rows (9041F red beet) located adjacent to a bed of six male rows (9041M Swiss chard). Row spacing was 50 cm and there was a 1 m gap between beds. The experimental plots were 3.2 m wide by 12 m long and included one bed of female rows (8 m) and the adjacent male bed (3 m). There were four replicates in a randomized block design. There were 11 treatments per replicate, with one nil herbicide treatment and the remaining ten receiving the herbicide Hammer® Force applied at ten different timings from mid-May to late September (Table 1). Treatments 10 and 11 included two application dates, the first in mid-June and the second in late August (Treatment 10) or mid-September (Treatment 11). All other crop inputs, including pre-trial weed control, disease control, fertilisers and irrigation were managed by the grower.

Trial 2 was located near Dunsandel, Canterbury (elevation 110 m asl). The sowing layout was similar to the Irwell trial, except plots were 3.3 m wide and 9 m long. The female line was No.11F red beet and the male line was No.11M red beet. There were nine treatments per replicate, and the timings ranged from mid-June to late-August (Table 2). All other crop inputs, including pre-trial weed control, disease control, fertilisers and irrigation were managed by the grower.

Percent crop damage was assessed by visually scoring male and female rows separately (where 0 = nil and 100 = dead) for each plot at 14 – 21-day intervals. For the Irwell site, there were seven assessments from 29 May to 2 October 2020. For the Dunsandel site, there were five assessments from 10 June to 31 August 2020. Plant height of both male and female rows were measured on 7 December 2020 at both sites.

The crops were desiccated with 2.5 L/ha of Reglone® (a.i. 250 g/L diquat, Group 22) with 1.5 L/ha of Uptake™ spraying oil on 3 February (Irwell) and 10 February (Dunsandel) 2021 and direct combined on 11 February (Irwell) and 19 February (Dunsandel). Seed collected from plots was sub-sampled, weighed, sieved and cleaned to calculate machine-dressed seed yield. Yield calculations included the area previously occupied by male rows, as this is the industry standard for calculating yield targets.

Weather data was accessed from NIWA's CliFlo database with applicable data taken from the Broadfields station (17603). Trial data were analysed using general ANOVA where appropriate in Genstat 19th Edition.

Results

Trial 1

Application of Hammer® Force on the 18 May 2020 (the earliest treatment date) gave 63% initial crop damage. This was the greatest initial damage caused by any of the treatments. However, the crop showed a gradual recovery with only 1.8% damage 137 days after application (Figure 1).

The 29 May and 15 June treatments showed a similar response, damage initially increasing and then recovering over time. Full recovery (0% damage) of these crops occurred 126 and 109 days after these treatments, respectively (Figure 1). Female rows were significantly less damaged ($p<0.001$) than the male rows (17% compared with 23%).

There was no significant difference in machine-dressed seed yield between treatments ($p=0.616$) at the Irwell site, with a mean yield of 1700 kg/ha (Table 1).

Table 1. Machine-dressed (MD) seed yield of red chard following treatment with Hammer® Force applied on different dates between May and September when grown near Irwell in the 2020-21 growing season.

Treatment	Herbicide and rate (mL/ha)	Application Date	Crop damage (%)		Height (cm)	MD yield (kg/ha)
			Male	Female	Female	Female
1	Nil	-	8	0	80	1780
2	Hammer® Force (150)	18.5.20	36	43	79	1580
3	Hammer® Force (150)	29.5.20	30	20	84	1560
4	Hammer® Force (150)	15.6.20	24	17	85	1790
5	Hammer® Force (150)	3.7.20	18	6	85	1670
6	Hammer® Force (150)	16.7.20	16	6	86	1660
7	Hammer® Force (150)	26.8.20	17	12	86	1640
8	Hammer® Force (150)	18.9.20	17	9	85	1740
9	Hammer® Force (150)	30.9.20	18	2	84	1770
10	Hammer® Force (150)	15.6.20 + 26.8.20	20	13	88	1820
11	Hammer® Force (150)	15.6.20 + 18.9.20	23	15	84	1760
		mean				**1700**
		LSD (P=0.05)	**8**	**7**		
		P value	**<0.001**	**<0.001**	**0.680**	**0.616**

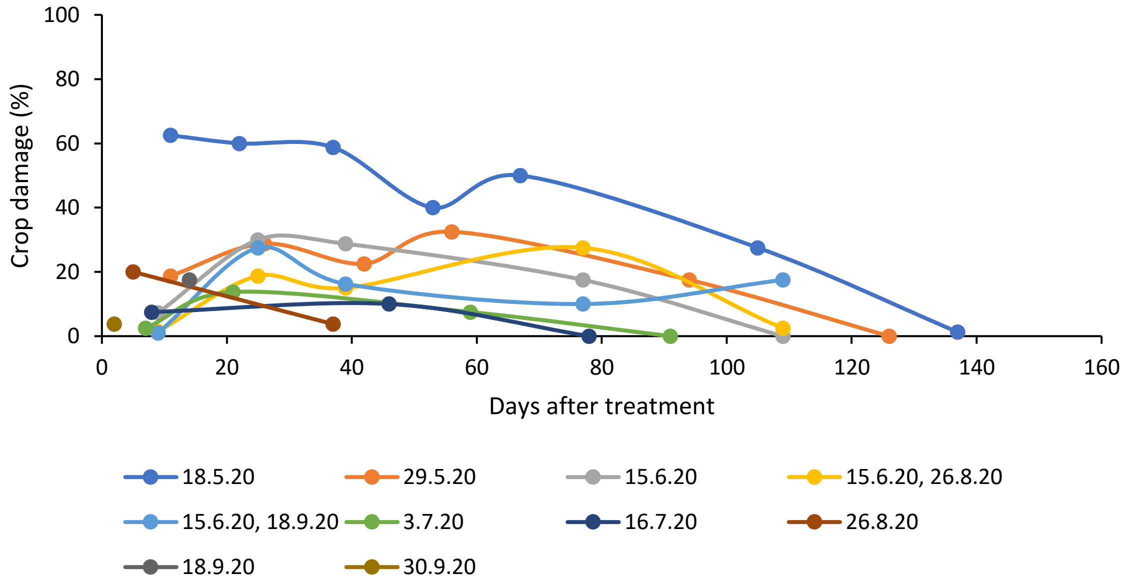

Figure 1. Crop damage scores (%) for female rows in a red chard crop grown near Irwell, Canterbury in the 2020-21 growing season following the application of Hammer® Force (a.i. carfentrazone-ethyl) at 150 mL/ha at 11 timings between mid-May and late-September.

Trial 2

For the single-dose treatments with Hammer® Force, average female damage was 32% compared with 28% in the male plants, however the difference between male and female rows was not significant (p=0.093). Damage in the untreated female rows was a combination of frost and leaf disease that was difficult to separate from herbicide damage (Table 1).

A double application of Hammer® Force on 2 June and 28 July (Treatment 8), gave the highest female herbage damage (63%), which reduced to 51% 52 days after treatment. A second application on 28 July increased crop damage to 80%. Crop plant density was significantly reduced (to 9 plants/m^2) by the repeat application when compared with all other treatments (that averaged 23 plants/m^2) (Table 2). Despite differences in crop damage and final plant number in Treatment 8, there was no difference in seed yield between treatments (mean yield 1200 kg/ha, p=0.992) (Table 2). This response occurred at both sites and reinforced earlier results that despite severe leaf herbicide damage occurring early in the season, plants recovered and produced similar yields to the untreated controls.

In the Dunsandel trial, different herbicide combinations were used in addition to a range of application timings. The inclusion of Stomp® gave greater (p<0.01) leaf damage in both the female and male plants than Hammer® Force alone or when Goltix® and Nortron® were added. Female plants had on average 34% damage with Stomp® added (Treatments 4 and 7), compared with 23 and 24% in the Hammer® Force alone (Treatments 2 and 5) and Goltix®/Nortron® treatments (Treatments 3 and 6), respectively. Male plants had on average 30% damage, whereas Hammer® Force alone was 20.8% and with Goltix®/Nortron® added was 23%. There was no difference in seed yield between the herbicide combinations (p=0.99).

Table 2. Average crop damage for male and female rows, plant density at harvest, plant height (female rows) at flowering and machine-dressed seed yield of red chard crops grown at Dunsandel, Canterbury using one of nine herbicide treatments in the 2020-21 growing season.

Treatment	Herbicide treatment (mL/ha)	Date of application	Leaf burn score (% chlorosis)		Plant density (m^2)	Height (cm)	Seed yield (kg/ha)
			Male	Female			
1	Nil	-	0	15	25	90	1160
2	Hammer® Force (150)	16.6.20	20	23	26	87	1180
3	Hammer® Force (150) + Goltix® (6 kg/ka) + Nortron® (1.5 L/ha)	16.6.20	22	22	22	86	1240
4	Hammer® Force (150) + Stomp® Xtra (2.5 L/ha)	16.6.20	29	33	20	83	1250
5	Hammer® Force (150)	28.7.20	25	25	25	85	970
6	Hammer® Force (150) + Goltix® (6 kg/ha) + Nortron® (1.5 L/ha)	28.7.20	25	30	27	84	1180
7	Hammer® Force (150) + Stomp® Xtra (2.5 L/ha)	28.7.20	33	38	24	83	1300
8	Hammer® Force (150)	2.6.20 + 28.7.20	46	53	9	79	1290
9	Hammer® Force (150)	26.8.20	23	30	22	83	1220
		LSD (p=0.05)	**8**	**9**	**6**		
		P value	**<0.001**	**<0.001**	**<0.001**	**0.133**	**0.992**

Summary

Red beet tolerance to the herbicide carfentarzone-ethyl (Hammer® Force) was investigated to determine the effect of application timing on crop damage and seed yield.

For the Irwell site, there were no strong relationships between temperature before or after application and damage at approximately 40 days. Previous work by Rolston *et al.* (2020) suggested that warmer temperatures in May caused greater crop damage than applications during the winter months, however in the 2020-21 season this was not shown.

Differences between sites may be associated with the parent lines used, where the Irwell site had a swiss chard male line and the Dunsandel male line was red beet. Also, damage to commercial seed crops where growers have applied carfentrazone is reported to vary, with crops east of SH1 (elevation 70 to 100 m asl) often receiving less damage than crops west of SH1 (James Taylor, SPS *pers. comm*.). The data from two years of trials indicates that even when severe leaf burn occurs from the use of carfentrazone, seed yields were only slightly reduced if at all.

References

Chynoweth, R and Rolston, P (2019). Can mallow be controlled in beet seed crops? *FAR Research Results Report 2018-19*: Pp. 126-127.

Rolston, P, Gunnarsson, M, and Chynoweth, R (2020). Red chard seed crop tolerance to herbicides used for mallow control. *SIRC Research Results 2019/2020*: Pp. 63-67.

White blister disease of radish in response to irrigation

Project code B19-02

Duration Year 2 of 3

Authors Diwakar (Wadia) Kandula, John Hampton (Bio-Protection Research Centre, Lincoln University) and Phil Rolston (FAR)

Location Fletcher Glasshouse, Lincoln University Nursery

Funding Seed Industry Research Centre (SIRC)

Acknowledgements David Birkett (Grower); Brent Richards and Leona Meachen (Lincoln University Nursery)

Key points

- Effect of irrigation on white blister of radish was investigated in a glasshouse experiment.
- White blister on radish leaves appeared 32 days after sowing (DAS) in the overhead watering treatment (OWT) and 48 DAS in the ground watered treatment (GWT).
- White blister on racemes appeared 77 DAS in OWT and 83 DAS in GWT.
- Percentage of infected racemes was greater for OWT than GWT.
- Infected leaf percentage and seed-bearing pod number in the two treatments did not differ.

Background

Albugo candida, the cause of white blister disease, is a seed and soil-borne pathogen. The disease reduces yield and quality of New Zealand radish seed crops (Braithwaite *et al.* 2018). Pathogen spread within the crop depends partly on the presence of wet leaves, or flowers, which allow spore germination, essential for disease initiation and spread. As seed growers routinely use overhead irrigation, a glass-house experiment was conducted to assess the impact of overhead versus ground watering methods on white blister disease development on radish grown for seed.

Methods

Radish seed (Red round type) with naturally infected seed-borne inoculum was sown in 10 L pots containing potting-mix on 27 October 2020 and housed in a glasshouse in a randomised block design with six replicates. Each unit had six pots with 4 plants/pot giving a total of 24 plants to mimic a canopy (Figure 1). The pots were placed in a large plastic tray which was filled with water. For the overhead watering treatment, water was applied twice a week (Monday and Friday) to wet the canopy. Care was taken (by placing a plastic sheet to plant height) to maintain a dry canopy for the ground watering treatment. Once every two days, plants were observed for disease occurrence while on 27 December 2020, 100 leaves from each unit were assessed for foliar disease symptoms.

On 28 December 2020 heavily infected material was collected from a radish field near Leeston, air dried for a couple of hours, placed in a multi-layered muslin cloth and dabbed on all the plants (to mimic air-borne inoculum). The overhead watering treatment received water to the canopy four hours after inoculation. Raceme tips were observed every two days for disease symptoms. Fifty seed-heads from each unit were thoroughly assessed for disease on 15 February 2021.

Figure 1. Experimental set-up in Fletcher glass-house, Lincoln University Nursery.

Results and Discussion

White blister disease (WBD) first appeared in the overhead watered treatments on 29 Nov 2020 (32 days after sowing (DAS)) and in the ground watered treatment on 15 Dec 2020 (48 DAS). Seed-borne inoculum was considered to be the main-source of this disease because the trial was located inside a glasshouse. There was no significant difference in the percentage leaves infected between watering treatment (Table 1).

Table 1. Percentage of leaves and raceme tips infected with white blister disease and seed-bearing pod number/plant in a glass-house experiment on 15 February 2021, Lincoln University Nursery (sown on 27 October 2020).

Irrigation treatment	**Incidence of White blister (%)**		**Seed-bearing pods (number/plant)**
	Leaves	**Raceme tips**	
Overhead Watering (OWT)	6.0	12.5	89
Ground Watering (GWT)	2.0	0.5	93
P value	**NS**	**p <0.05**	**NS**
LSD (p=0.05)		**5.18**	

Note: Cell highlighted yellow indicates treatment with the lowest incidence of disease.

White blister disease on the inflorescence (flowers, raceme tips and immature pods) first appeared on 13 January 2021 (77 DAS) in OWT and on 19 January 2021 (83 DAS) in GWT. As the plants were artificially inoculated 49 DAS, this disease development could have been the result of seed-borne inoculum or artificial inoculation. A significantly higher number of raceme tips/seed heads were infected (Figure 2) in OWT than GWT (Table 1). Seed bearing pod number in both the treatments did not differ.

Summary

White blister disease appeared earlier and was more prevalent on raceme tips in the overhead watering treatment than in the ground water treatment. These results indicate that overhead irrigation is a major factor contributing to disease spread within the crop.

Reference

Braithwaite, M, Chynoweth, R, Gunnarsson, M, Braithwaite, L, Harvey, I and Rolston, P (2018). White blister disease control in radish seed crops. *New Zealand Plant Protection* 71: 325–33

Figure 2. White blister disease on an infected seed-head of radish

Alternative pollinators for seed crops – drone fly mass rearing and utilisation

Project code B19-07

Authors Brad Howlett and Sam Read (New Zealand Institute for Plant & Food Research), Phil Rolston and Fiona Anderson (FAR)

Duration Year 3 of 3

Location Darfield, Greendale and Leeston, Mid-Canterbury

Funding MPI SFF and Seed Industry Research Centre (SIRC)

Acknowledgements Hamish Redfern, Graeme Marshall and Stu Lemon (trial hosts); Francesca Schmidlin (Plant & Food Research); Richard van Garderen and James Taylor (South Pacific Seeds); Mark Bond (Bond Earth Works)

Key Points

- Drone flies can be raised in-field, either in ditches or portable 1000 L tank systems.
- Individual flies can remain in the field for several days providing pollination services.
- The number of pupae produced was comparable between systems.
- In the carrot and radish crops, drone flies sometimes out-numbered honey bees. This was most likely on cooler days.
- Drone fly abundances tended to decrease with distance from the rearing unit.
- Drone flies were up to 11 times more efficient than honey bees at pollinating carrot and up to three times more efficient at pollinating radish crops. This was largely due to their more frequent movement between male fertile and male sterile lines.
- Outside of the test paddock, drone fly populations did not increase above naturally occurring populations.

Background

Honey bees (*Apis mellifera*) are currently the only pollinators used extensively by growers in insect-pollinated seed crops in New Zealand. Bringing in hives for crop pollination is a significant cost to growers (Ministry for Primary Industries, 2018). However, many alternative bee and non-bee flower visiting insects have been identified as capable of pollinating a wide range of vegetable seed crops. These include NZ native bee species and numerous fly species (Howlett *et al.* 2021a). The simple life-cycles of some alternative species offer the potential for low-cost management systems. Incorporating other pollinators can add resilience to pollination systems (Garibaldi *et al.* 2013).

The drone fly is a non-bee pollinator that has shown significant promise as a managed insect (Howlett *et al.* 2021a). It is an effective pollinator of a range of crops, including many vegetable seed crops, and has a simple lifecycle (larvae develop on decaying organic matter in water), making it easy to rear on a range of readily available substrates. It also appears to complement honey bee pollination by being more active than honey bees at cooler temperatures. Previous work by Howlett *et al.* (2020) found that drone flies raised off-site and transferred to seed fields had potential to deliver pollination services for many days; tagged flies found in the crop two weeks after release. However, there have been concerns regarding the movement of drone flies onto neighbouring farms, particularly dairy farms where larvae have been found pre-pupating in cattle feed. This can lead to health issues for the animals consuming contaminated feed. To avoid this and any other unforeseen issues, the mass-rearing of drone flies on arable farms must avoid spreading large populations into the surrounding landscape.

Focus has been placed on simple, low-cost systems to raise drone fly populations within the seed field, with the intention that growers would be able to manage their own flies without the added cost of contractors. Two systems had been developed: (1) open ditches (6 x 0.5 x 0.4 m) and, (2) small portable containers (54 L systems) containing saturated decomposing organic matter (Howlett *et al*. 2020). The portable rearing system enhances the likelihood of pollination by drone flies.

However, a fast rate of evaporation on hot days required frequent addition of water to the rearing substrate. Although each container was capable of rearing up to 1000 drone flies, counts were more commonly 200-400. This was fewer than in open ditches (approximately 6,000).

The aim of this experiment was to test a larger capacity portable system and to determine the distance drone flies might travel in the environment.

Methods

Trial 1 – Enhancing drone fly populations for pollination in vegetable seed crop fields.

Two mass rearing systems were assessed: open ditches (4 x 0.4 x 0.4 m) and a 1000 L portable tank system. At the Darfield (carrots) and Leeston (radish) sites, four 1000 L tank systems were placed in each crop paddock. At the Greendale site, four tanks were placed in a carrot seed crop (Figure 1), and there were four ditches along the edge of the adjacent radish crop 50 m away (Figure 2).

The tank systems were created from modified 1000 L bulk containers. The containers were fitted with spouting on all four sides to create a pathway for pupating larvae to exit the tank. Once in the spouting, they would drop into a 60 L storage container filled with wood shavings, allowing them to develop into adult flies. A rectangular slot was cut into one side of these pupae containers which allowed adults to emerge and migrate into the field. This slot was covered with chicken wire to prevent rodent predation, and the top of the tank was also covered with bird netting to prevent bird foraging on larvae. Untreated grass clippings were used as the rearing substrate, with each 1000 L container filled with grass and then water. Containers were left in the fields for the duration of flowering and stirred periodically throughout each week to improve substrate fermentation.

Figure 1. The modified 1000 L containers filled with grass clippings and installed in a hybrid carrot crop (Adapted from Howlett *et al.* 2021b).

Figure 2. Drone fly rearing ditches, with black containers providing pupation sites at the end of each ditch (Adapted from Howlett *et al* 2021b).

The ditch systems (dimensions: 4 x 0.4 x 0.4 m) were formed from trenches dug 5 m apart at the paddock's edge. They were lined with heavy duty polythene (200 microns thick). PVC panels along the perimeter prevented larvae from escaping into the surrounding vegetation. Instead, migrating larvae were channelled into pupation containers positioned at each end of the ditch via a side slot in the plastic liner.

Surveillance and data collection

Developing larvae and pupae from the drone fly rearing ditches and containers were surveyed across the three fields at multiple time points, starting just before flowering and finishing after flowering. Larvae counts were conducted on eight occasions beginning on 10 November 2020 and concluding on 11 March 2021. On survey days, the ditches were stirred to dislodge larvae from substrates and distribute individuals evenly before sampling, and larvae counts were conducted by sampling 750 mL (3x250 mL subsamples) from each ditch. The 1000 L containers were sampled from the upper 30 cm.

Pupae counts were conducted on nine occasions beginning on 2 December 2020 and finishing on 1 April 2021. To conduct counts, a known volume of woodchips (2.5 or 1 L) from the 6 L of wood chips within each box were sifted through and pupal cases counted.

Field surveys were used to assess drone fly and honey bee flower visitation, with daytime observations taken at 10 am, 12 pm, 2 pm and 4 pm. Depending on the placement of the portable tanks, observation sites were placed nearest to the tank, mid-distance and then farthest from the tanks at the edge of the paddock. In carrot crops, observations were conducted on 150 fully flowering umbels (within a 5-10 m radius), of which 75 were male sterile and 75 were male fertile, with umbels containing at least 30 % open flowers. In radish crops, counts of flower-visiting drone flies and honey bees were conducted by walking along 10 m of two individual rows (one sterile, one fertile) at each observation site.

Pollinator insect behaviour observations.

Insect movement between carrot umbels of hybrid lines was assessed by tracking individual insects for up to 14 minutes (min). Movement between umbels within and between hybrid rows (sterile and fertile) was recorded. A similar method was used for radish, where foraging rate (stigmas/anthers visited per time unit) was assessed by counting the number of flowers each individual insect foraged over a certain period of time (up to 8 min if possible), with intra/inter row movements recorded. Using this data, the relative effectiveness of drone flies and honey bees was determined. This was done by comparing the frequency of movements between fertile and sterile inflorescences, estimated stigmatic pollen delivered (Howlett *et al.* 2021b) and their within-field abundances.

Trial 2 – Drone fly migration from mass-rearing sites and natural populations across Canterbury

Drone fly migrations out of their placement field was assessed using window trapping in and around carrot and radish seed crop fields during January and February 2019, 2020 and 2021. Naturally occurring drone fly abundance was determined on 12 separate Mid-Canterbury dairy farms and six arable farms, ranging in location from Lincoln to Ashburton Forks. Ninety traps were placed on dairy farms and 270 on arable farms, with traps installed next to landscape features such as bare fence-lines, effluent ponds and tall shelterbelts. This enabled a comparison between mass-rearing locations and areas without purposeful drone fly sources.

Results and Discussion

Trial 1

Larvae and pupae production. The estimated numbers of larvae within the 1000 L portable systems varied substantially throughout the four-month survey period. At the Darfield and Greendale sites, peak larval populations were over 30,000, whereas the Leeston site had 20,000 larvae. Larvae counts were highest in November or December and declined from January onwards. Peak populations varied between containers at each site, sometimes by up to two weeks, which gave good spread of pupae production. Despite large larvae numbers, the pupae evolved were 10,400, 7,920 and 16,840 at the Darfield, Greendale and Leeston sites, respectively. For the ditch systems, larvae numbers peaked in December with an estimated population of 39,000, approximately two weeks later than the portable tanks. A total of 13,903 pupae were counted across the four Greendale ditches, giving an estimated population of 15,340 pupae produced during the carrot flowering period and 15,350 to 19,730 for the radish flowering period.

The 1000 L system did not dry out and the tanks were easy to transport. The number of pupae per litre of substrate was increased in comparison with the smaller tanks used in the previous year, but further work is required to prevent predation and damage from birds and rodents.

Drone fly abundance in the crop. In the carrot fields, drone flies were observed on all survey dates. At Darfield, 123 drone flies were detected compared with 193 honey bees. At Greendale on radish, there were 25 drone flies to 75 honey bees, although the percentage of pollinators that were honey bees was variable across survey days, from a low of 51 % (13 January) to a high of 80% (3 February). On two of the five survey days at Greendale and Darfield, drone flies out-numbered honey bees. Drone fly density tended to be in greater (p=0.02) nearest their rearing containers compared with elsewhere in the field. Further trials would be required to determine the distance over which containers influence abundance, therefore allowing a recommendation of tank distribution throughout the field.

In the radish fields, honey bees were more frequently observed than drone flies on radish inflorescences across all survey days. Differences between the species in terms of optimum working temperature was demonstrated in the carrot crop, with drone flies more abundant than honey bees on days when maximum temperature was less than 24 °C. On warmer days (28.2, 25.3 °C) honey bees were more abundant, which emphasises the complementarity of pollination services these two insects provide under Canterbury's variable conditions.

Movement between hybrid lines in the field. To pollinate hybrid crops effectively, pollinators must move from fertile (male rows) to sterile (female) drill rows to deliver the pollen. In the carrot crops, drone flies spent similar amounts of time on flowering umbels to honey bees (26 and 30 seconds (sec), respectively). On average, drone flies moved from fertile to sterile umbels four times faster than honey bees. In the radish crops, the time spent on each inflorescence was equivalent (13.7 and 13.2 sec for drone flies and honey bees respectively). Drone flies moved between fertile and infertile flowers on average within 2.2 min, whereas honey bees took on average 7.0 min.

Pollination efficiency. Based on the fertile to sterile movement, and median pollen delivery per time taken, drone flies are an estimated 11 times more efficient at pollinating carrot crops than honey bees. In radish crops, drone flies were estimated to be three times more efficient pollinators than honey bees. Despite this, overall, honey bees were more effective pollinators in radish fields because they were much more abundant in the fields assessed. Optimising mass rearing of drone flies, and growing plants which would retain them in the area, could greatly improve their effectiveness as pollinators in radish crops.

Trial 2

There was no evidence that the mass-rearing of drone flies in vegetable seed crop fields resulted in elevated numbers of drone flies in the surrounding environment when compared with naturally occurring numbers found on Canterbury arable and dairy farms. Based on current knowledge, large drone fly populations are most likely a problem for dairy farms. However, the current study demonstrated that dairy farms support comparable (if not higher) drone fly populations through their provision of suitable larval habitats (e.g. effluent ponds) than sites of mass drone fly rearing. When increased drone fly population production is implemented, further monitoring will be required to ensure any natural populations are not being exacerbated.

Summary

Using modified 1000 L tanks within crop fields can be an effective and straight forward system for growers to rear several thousand pollinators on site. The advantage of this newly trialled method is that the containers can be moved by growers. 8,000-17,000 pupae per tank were produced. However, further work is required to safeguard the apparatus from animal predators. Drone fly densities tended to be greatest adjacent to their rearing site and decrease with increasing distance from the system. It was estimated that, based on their quicker period of movement between fertile and sterile inflorescences, drone flies were 11 times more efficient than honey bees at pollinating carrot seed crops and about three times more efficient in radish crops. However, further work with different hybrids of varying attractiveness is required to verify these findings.

References

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Alternatives to diquat for pre-harvest seed crop desiccation of beets and radish

Project code	B20-02
Duration	Year 1 of 2
Authors	Phil Rolston and Owen Gibson (FAR)
Location	Dunsandel and Leeston, Mid-Canterbury
Funding	Agmardt and Seed Industry Research Centre (SIRC)
Acknowledgements	Glenn Smith (Irwell) and John Michaels (Dunsandel) (trial hosts); James Taylor (grower contacts) and Jane Bermester (seed quality tests) (South Pacific Seeds); NZ Arable (trial operators); Huong (Pham Thi Tam Huong) and John Hampton (Bio-Protection Research Centre, Lincoln University)

Key points

- Diquat had faster brown-out and larger reduction in stem moisture than the other chemical desiccants but final seed yield was the same.
- GreenMan™ organic bioherbicide was as effective as the alternatives (Buster®, Hammer® Force) but five times more expensive.
- Seed germination and TSW were not affected by the treatments.

Background

New Zealand is the world's eighth largest exporter of vegetable seeds, supplying around 50% of the world's hybrid radish, carrot and beet seeds. While seed yield is important, being able to meet the quality standards required by the importing countries is vital for the New Zealand vegetable seed industry. The indeterminate reproductive growth habit of many vegetable species means that seed development is non-uniform, and seed quality, particularly germination, can be variable as a result.

To accelerate the drying of vegetative tissue to improve seed harvest operations, growers apply a chemical desiccant, diquat dibromide (Group 22 herbicide). However, there are two problems with its use: (I) diquat can reduce seed germination (Miller 2002; Trivedi et al. 2010), and (II) the European Union has recently withdrawn registration for diquat use because of environmental concerns (O. J. 2020). Diquat is registered in New Zealand. However, a ban here, or from European seed buyers, would leave growers with no alternative product or method for desiccating seed crops.

This project will evaluate alternatives to diquat as a preharvest desiccant. In the short-term, this will be by investigating the use of other chemical desiccants. In the longer-term, more environmentally acceptable options, such as organic products and mechanical methods, will be explored.

Methods

Trial 1. Red beet

The trial was located near Dunsandel, Canterbury (elevation 110 m asl) in a commercial hybrid red beet seed crop. The female line was No.11F red beet and the male line was No.11M red beet. All crop inputs, including pre-trial weed control, disease control, fertilisers and irrigation were managed by the grower.

All desiccant treatments (Table 1) were applied on 10 February 2021 with a 3 m hand held boom fitted with six 110 02xr tee jet nozzles at a water rate of 200 L/ha, with the exception of GreenMan™ which was applied in 400 L/ha water (Table 1). Plots were 3.3 by 9 m, treatments were replicated four times in a randomized block design. The windrow treatment was simulated using a hedge-trimmer to cut stems 10 cm above ground level the day prior to desiccation. Two visual scores of plant brownout were undertaken on 12 and 15 February (Table 1). Stem and seed moisture content were assessed by oven drying stems at 70°C for 36 hours (h) on 9 ,15 and 18 February (days 0, 6 and 9, respectively).

The plots were machine harvested on 19 February with a Sampo plot combine with vertical side knives cutting 2.1 x 9 m plots. A sub-sample of seed was cleaned by sieving (2.8 mm) and blowing off light material using a Dakota seed blower. Seed yields were adjusted to 12% seed moisture content and for the land occupied by the male rows (Table 1).

Trial 2. Radish

The trial was located near Irwell (Canterbury) in a commercial 'French breakfast' hybrid radish crop with the female line no.11121 and male line no.11122. All crop inputs except the harvest desiccants were applied by the grower. The plots were 3.3 m wide and consisted of one female bed (4 m long). There were six desiccant treatments with four replicates in a randomized block design. The desiccant treatments (Table 2) were applied on 19 March 2021. The windrow treatment was simulated using a hedge trimmer to cut stems at 10 cm above ground level on the same day as desiccants were applied. Visual scoring of plant brownout was undertaken on 1 and 7 April, and stem and seed moisture content assessed by oven drying stems at 70°C for 36 h on 19 March, 26 March and 7 April (days 0, 7 and 19, respectively). The plots were machine harvested on 7 April by cutting 1.65 m x 4 m plot length, with a Sampo plot combine. A sub-sample of seed was cleaned by sieving (2.8 mm) and light material removed with a Dakota seed blower. Seed yields were adjusted to 8% seed moisture content and for the land occupied by the male rows (Table 2).

Desiccant treatments

There were six desiccant treatments per replicate. Treatment 1 was treated as the control and represented the host farm practice; Reglone® (active ingredient (a.i.) 200 g/L diquat, Mode-of-Action Group 22) with Contact™ Xcel 5 mL/100 L water (a.i. 980 g/L Linear alcohol ethoxylate). Treatment 2 was an organic registered bioherbicide, GreenMan™ (a.i. 650 g/L fatty acids) + Expedient® (a.i. 704 g/L ethyl and methyl esters of canola oil fatty acids with 196 g/L non-ionic surfactants). Remaining treatments consisted of three herbicides that have previously been used as desiccant options; Buster® 5 L/ha (a.i. 200 g glufosinate ammonium/L, Group 10); Buster® 5 L/ha plus Sharpen® 25 g/ha (a.i. 700 g/kg saflufenacil g/L, Group 14); and Hammer® Force 250 mL/ha (a.i. 240 g/L carfentrazone-ethyl, Group 14) plus Hasten™ 1 L/ha (a.i. 740 g/L fatty acid esters) plus Contact™ Xcel 5 mL/100 L water (a.i. 980 g/L Linear alcohol ethoxylate).

Seed evaluations

Seed germination, thousand seed weight (TSW) and conductivity of water after seeds had been soaked for 24 hours was assessed using standard seed laboratory protocols by South Pacific Seeds at Methven. The seed conductivity readings are an estimate of seed vigour and low readings are associated with high seed vigour.

All ANOVA analysis used GenStat v19 package**.**

Results and Discussion

In the red beet trial, seed yields averaged 1,160 kg/ha, with no difference between the chemical desiccants. However, windrowing reduced seed yield relative to the Buster® and Hammer® Force treatments (Table 1). There were no differences between treatments in seed quality parameters: germination averaged 81%, TSW averaged 10.1 g and seed conductivity averaged 341 µS/cm/g.

Diquat produced the most rapid brown-out compared with the alternative chemical treatments (Table 1) and was similar to the windrow treatment six days after harvest. The GreenMan™ product had higher brown-out percentage than the alternative desiccants at both evaluation timings.

Seed moistures declined from 63% (data not shown) pre-treatment to 9 and 12% in the diquat and windrow treatments, 15 to 20% in the two Buster® treatments and 31 and 42% in the GreenMan™ and Hammer® Force treatments, respectively (Table 1). Treatments with seed moisture contents >14% would need to be dried for safe storage.

In the radish trial, the average seed yield was 550 kg/ha, with no difference between treatments (Table 2). The radish had an average pre-treatment stem moisture content of 72% (data not shown), which declined to 25 and 30% for the diquat and windrowed treatments, respectively (Table 2). The remaining treatments had higher stem moisture content at harvest, between 50 and 65% (Table 2).

There were no differences between treatments on seed germination (average 83%) and TSW (average 12.2 g). The seed conductivity was lowest for the diquat control (274 µS/cm/g) and highest in the Greenman™ (483 µS/cm/g) treatment. Across the six treatments seed conductivity was higher in the treatments that had higher crop moisture at harvest (R^2=0.5). However, the seed is protected by the pod and thus has no direct contact with the desiccant. This suggests that the handling of the seed post-harvest contributed to these higher readings and requires further investigation.

The cost of GreenMan™ is reducing, but at the current price of $33/L or $1056/ha desiccating a crop would be at least five times more expensive than with the other options.

Summary

Effective alternatives to diquat do exist should seed growers lose access to this desiccant. However, the alternatives are generally slower in their dry-down rates and/or more expensive. The organic desiccant GreenMan™ was similar to the other alternative chemicals in efficacy but was more expensive.

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Table 1. Seed yield, adjusted to 12% seed moisture content, brown-out, stem moisture and seed moisture content for red beet following one of six desiccation programmes when grown near Dunsandel in the 2020-21 growing season.

Treatment No.	Desiccant and rate of application (10 February 2021)	Brown-out (%)		Stem moisture (%)		Seed moisture content (%) (18 February)	Seed yield (kg/ha)
		12 February	15 February	15 February	18 February		
1	Reglone® (3 L/ha) + Contact™ XCEL	45	84	57	57	9	1280
2	Buster® (5 L/ha)	9	30	65	62	20	1336
3	Buster® (5 L/ha) + Sharpen® (25 g/ha)	6	30	66	67	15	1460
4	Hammer® Force (250 mL/ha) + Hasten™ (1 L/ha) + Contact™ XCEL (5 mL per 100 L water)	8	13	66	61	42	1820
5	GreenMan™ 8% (32 L/ha) in 400 L/ha + Expedient® (2.0 L/ha)	20	40	65	67	31	1330
6	Windrow	38	85	31	19	12	853
	LSD (p=0.05)	**6**	**9**	**6**	**8**	**9**	**(547)***
	P value	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.024**

*unsupported LSD as P value not significant.

Table 2. Seed yield, adjusted to 8% seed moisture content, brown-out, stem moisture and seed moisture content of European radish following one of six desiccation programmes when grown near at Irwell in the 2020-21 growing season.

Treatment No.	Desiccant and rate of application (19 March 2021)	Brown-out (%)		Stem moisture (%)		Seed yield (kg/ha)
		1 April	7 April	26 March	7 April	
1	Reglone® (3 L/ha) + Contact™ XCEL	100	90	57	30	550
2	Buster® (5 L/ha)	63	68	75	57	530
3	Buster® (5 L/ha) + Sharpen® (25 g/ha)	93	68	71	50	600
4	Hammer® Force (250 mL/ha) + Hasten™ (1 L/ha) + Contact™ XCEL (5 mL per 100 L water)	10	25	72	56	570
5	GreenMan™ 8% (32 L/ha) in 400 L/ha + Expedient® (2.0 L/ha)	14	30	73	65	580
6	Windrow	100	100	22	25	450
	LSD (p=0.05)	**13**	**11**	**6**	**19**	**(98)***
	P value	**<0.001**	**<0.001**	**<0.001**	**0.002**	**0.058**

*unsupported LSD as P value not significant.

Stem rust control in ryegrass seed crops

Project code	H19-03
Duration	Year 3 of 4
Authors	Richard Chynoweth, Phil Rolston and Ben Harvey (FAR), Nick Davies (AgResearch)
Location	Greendale, Mid Canterbury (Greendale 43 28’ 45.89” S, 172 04’ 19.04” E)
Funding	Seed Industry Research Centre (SIRC)
Acknowledgements	Graeme Marshall (trial host); NZ Arable (trial operator)

Key Points

- Turf-type perennial ryegrass seed yield was increased from 1028 kg/ha (untreated control) to 2780 kg/ha following three fungicide applications in a trial at Greendale, Canterbury.
- Increases in seed yield were attributed to observed reductions in the incidence of stem rust pustules.
- Treatments including the succinate dehydrogenase inhibitor (SDHI) Elatus™ Plus (a.i. 100 g/L benzovindiflupyr, Group 7) gave the best disease control, highest seed yield and largest margin-over-cost ($3527/ha) in this trial.
- Treatments utilising two SDHIs in combination with Proline® (a.i. 250 g/L prothioconazole, Group 3), one at at head emergence and one at flowering, provided adequate protection until harvest, thus achieving the fungicide withholding periods.

Background

Stem rust disease, caused by *Puccinia graminae*, can result in seed yield losses of 20 to 50% in ryegrass. Turf ryegrass and some overseas forage ryegrasses are particularly susceptible to infection and subsequent seed yield loss. While there are good fungicide options for managing stem rust, they must be applied before the disease becomes symptomatic as the initial infection and damage to vascular tissue occurs under the leaf sheath and is hidden from sight. Research in Oregon, USA, has shown that leaf wetness at sunrise and warm temperatures are major drivers of disease progression (Pfender 2003). A prediction model has been developed in Oregon and has provided growers with an early warning of conditions that favour the disease.

This report provides an update from Year 3 of a project to validate the Oregon model for New Zealand conditions. Validation of the model requires field trials with nil and typical fungicide treatments to determine the onset of stem rust and to help predict when follow up fungicide applications may be required.

The use of fungicides on ryegrass seed crops presents multiple challenges to New Zealand growers. Withholding period, development of resistant pathogen strains, and endophyte preservation are all considerations when deciding on a fungicide treatment regime. Two new fungicides registered in 2020-21 for use in ryegrass have not previously been evaluated in FAR/SIRC trials. In Oregon, some growers are using crop oils instead of a fungicide for their last application (R. Hydes, pers comm) and this was included as a treatment. This report seeks to investigate a number of possible fungicide programmes in order to better understand the options for growers.

Methods

A trial was designed to collect information on the onset of stem rust and the effect of fungicide applications and timings in ryegrass seed crops in Canterbury during the 2020-2021 growing season.

The trial was established in an irrigated second year seed crop (sown in autumn 2020) of ‘AllSport 4’, a turf perennial ryegrass. The paddock and all inputs except fungicides and plant growth regulator (PGR) were managed by the grower. The plots were 11 x 3.3 m with ten treatments replicated four times in a randomized block design. Moddus® Evo (active ingredient (a.i. 250 g/L trinexapac ethyl) PGR was applied at 1.6 L/ha (400 g ai/ha) on 10 November 2020. The trial evaluated ten fungicide treatments, with various products and application dates, as shown in Table 1. The fungicides evaluated were Proline® (a.i. 250 g/L prothioconazole, Group 3), Seguris Flexi® (a.i. 125 g/L isopyrazam, Group 7), Vimoy® Iblon® (a.i. 50 g/L isoflucypram, Group 7), Elatus™ Plus (a.i. 100 g/L benzovindiflupyr, Group 7) and Comet® (a.i 250 g/L pyraclostrobin, Group 11). Applications were made at Growth Stage (GS) 32 (10 November 2020), late head emergence (3 December 2020), early flowering (GS 61, 8 December 2020) and seed fill (GS 73, 28 December 2020).

Sampling was carried out approximately weekly from 11 December 2020 to 19 January 2021. Twenty-five stems were selected at random from each plot and assessed for presence or absence of stem rust; lesions per stem were counted where stem rust was present. These data (as well as weather data) were then used to determine whether or not to apply the two later fungicide applications to treatment 2, according to the prediction model. In this case, the model indicated that the threshold lesion density had been reached, and so these fungicide applications went ahead. The trial was windrowed on (23 January) and combine-harvested on January 27, 2021. The seeds were dressed to a First-Generation Seed Certification Standard.

Stem rust prediction model. Managing stem rust in ryegrass is challenging, as prior to the stem being fully elongated a proportion of the infection is not visible. The stem rust prediction model is a modified version of the Oregon State University stem rust model, "STEMRUST_G" (Pfender *et al*. 2014), adapted for New Zealand. The modified model uses regular measurements of canopy temperature, rain, humidity, and leaf wetness when available, in this case every 15 minutes. The key weather parameters affecting stem rust infection development are leaf wetness and temperatures for the 2-hour period after sunrise. The model uses thresholds based on observed stem rust pustule density and weather data for the application of triazoles (Group 3) and strobilurins (Group 11) derived from an Oregon experiment. The model's effectiveness was evaluated by using it to determine the decision for a mid- and late-December fungicide treatment (Treatment 2).

Statistical analysis included general analysis of variance (ANOVA) and linear regression, using Genstat® 19th edition (VSN International Ltd, UK).

Results and Discussion

All fungicide treatments increased seed yield above the untreated control (Table 1). Seed yield could be described by stem rust disease incidence (Figure 1). The most effective fungicide treatment increased relative seed yield by 170% when compared with the untreated control and represented the highest margin-over-fungicide (MoC) cost (Table 1). This fungicide treatment (Treatment 6) increased profits by $3,527/ha over the untreated control and included the newly approved SDHI fungicide Elatus™ plus. A second new fungicide, Vimoy® Iblon® (Treatment 5) produced a seed yield and MoC that were not significantly different to the SDHI standard, Seguris Flexi® (Treatment 4).

Fungicide application at PGR timing proved invaluable, treatments that omitted this timing were not able to provide adequate disease protection. Omitting an additional fungicide at head emergence (Treatment 3) gave the lowest seed yield apart from the untreated control. This treatment relied on the prediction model to determine whether an application of fungicide was required – this model will be discussed in a separate report.

Treatments which received no fungicide after 18 December (mid-flowering) met the 35 day withholding periods for prothioconazole. Fungicide on the final application date (28 December) was of limited effectiveness in yield and MoC. These treatments (Treatments 2, 3, 8, 9 and 10) did not perform any better than treatments that omitted this timing, provided they had fungicides at timings 1 and 2, suggesting that a fourth fungicide application may not be economically viable when SDHI fungicides are applied during head emergence and flowering. Thus, it is not possible to assess whether the addition of the crop oil (Hasten™) treatment had merit.

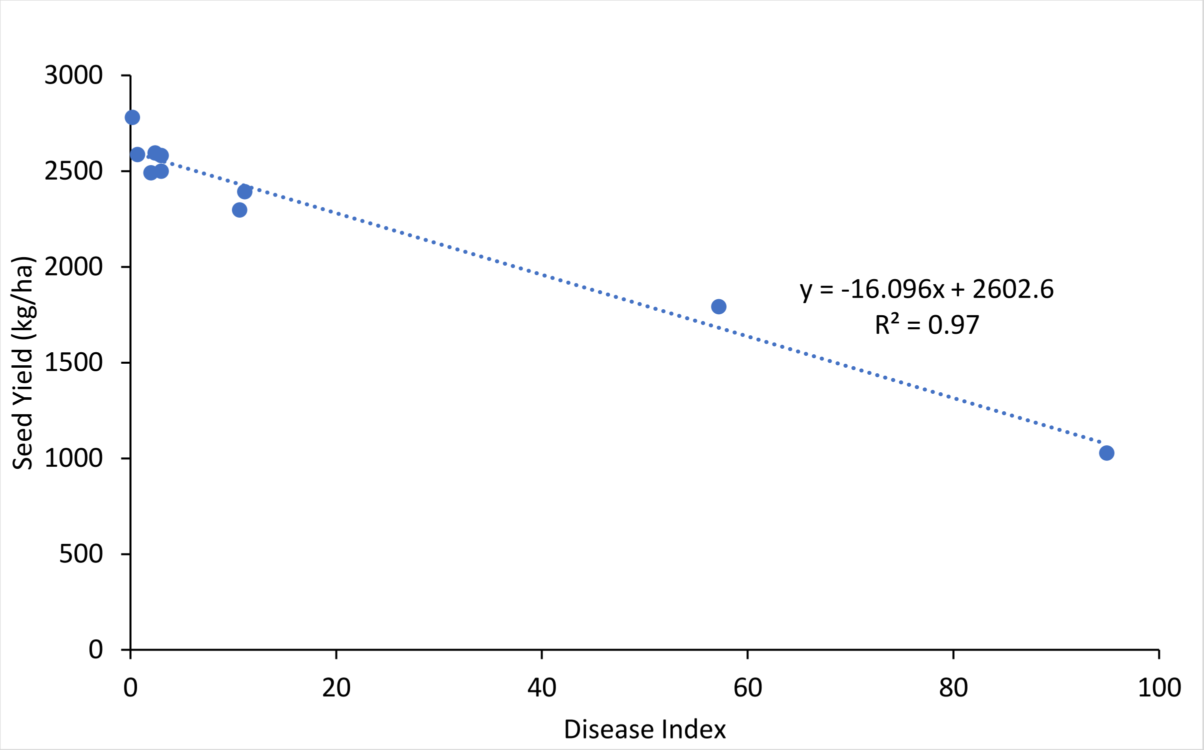

Figure 1: Relationship between disease index and mean seed yield of turf ryegrass (cv. Allsport 4) when treated with 10 fungicide treatments. Disease Index was calculated as the average number of pustules per stem multiplied by the percentage of stems that are infected.

Summary

A trial was established to investigate the effectiveness of a range of fungicide treatments in controlling stem rust in a turf ryegrass seed crop. Fungicide treatments were able to increase seed yield by up to 170% compared with the untreated control. The increase in seed yield was closely correlated to decreases in observed stem rust incidence. The relative merits of a range of different fungicides and timings were identified.

References

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Table 1. Seed yield and stem rust infection at harvest of perennial ryegrass, cultivar Allsport 4, treated with ten different fungicide programmes and grown under irrigation near Greendale, Canterbury in the 2020-21 growing season. Seed yield and margin-over-fungicide cost numbers followed by different letters are significantly different from each other.

Treatment No.	Fungicide treatments, rates (L/ha) and application dates				Seed Yield (kg/ha)	Disease Index[2]	Margin-over Fungicide-Cost ($/ha)
	10 November[1]	3 December	18 December	28 December			
1	-	-	-	-	1028 f	95	0 a
2	-	Proline® (0.4) + Seguris Flexi® (0.6)	Proline® (0.4) + Seguris Flexi® (0.6)	Proline® (0.4) + Comet® (0.8)	2392 cd	11	2604 c
3	-	-	Proline® (0.4) + Seguris Flexi® (0.6)	Proline® (0.4) + Seguris Flexi® (0.6)	1793 e	57	1427 b
4	Proline[3]® (0.4)	Proline® (0.4) + Seguris Flexi® (0.6)	Proline® (0.4) + Seguris Flexi® (0.6)	-	2500 bc	3	2891 cd
5	Proline® (0.4)	Proline® (0.4) + Vimoy® Iblon® (1.5)	Proline® (0.4) + Vimoy® Iblon® (1.5)	-	2587 b	1	3027 d
6	Proline® (0.4)	Proline® (0.4) + Elatus™ Plus (0.75)	Proline® (0.4) + Elatus™ Plus (0.75)	-	2780 a	0.2	3527 e
7	Proline® (0.4)	Proline® (0.4) + Seguris Flexi® (0.6)	-	-	2298 d	11	2565 c
8	Proline® (0.4)	Proline® (0.4) + Seguris Flexi® (0.6)	Proline® (0.4) + Seguris Flexi® (0.6)	Spraying oil (Hasten™) (9.4)	2492 bc	2	2708 cd
9	Proline® (0.4)	Proline® (0.4) + Seguris Flexi® (0.6)	Proline® (0.4) + Comet® (0.8)	Proline® (0.4) + Seguris Flexi® (0.6)	2581 b	3	2953 d
10	Proline® (0.4)	Proline® (0.4) + Seguris Flexi® (0.6)	Proline® (0.4) + Seguris Flexi® (0.6)	Proline® (0.4) + 0.8 Comet®	2595 b	2	2983 d
				LSD (p=0.05)	**153**	**20**	**329**
				P value	**<0.001**	**<0.001**	**<0.001**

[1]treatments applied at; GS 32 with PGR, head emergence, flowering and flowering + 10 days. [2]Disease Index is equal to the average number of pustules per stem multiplied by the percentage of stems that are infected. [3]Proline® (a.i. 250 g/L prothioconazole, Group 3), Seguris Flexi® (a.i. 125 g/L isopyrazam, Group 7), Vimoy® Iblon® (a.i. 50 g/L isoflucypram, Group 7), Elatus™ Plus (a.i. 100 g/L benzovindiflupyr, Group 7) and Comet® (a.i 250 g/L pyraclostrobin, Group 11). **Note**: Treatments highlighted green were applied based on the model as described. Entries highlighted yellow are among the best performing treatments. Margin-over-fungicide costs are based on the contracted ryegrass seed price of $2.15/kg.

Managing take-all disease in ryegrass seed crops with Trichoderma

Project code	H19-03-04
Duration	Year 2 of 4
Authors	Diwakar (Wadia) Kandula, John Hampton (Lincoln University) and Phil Rolston (FAR)
Location	Ashton, Mid-Canterbury (44° 02’ 09.31” S; 171° 46’ 24.3” E)
Funding	Seed Industry Research Centre (SIRC)
Acknowledgements	NZ Arable (trial operator); Paul Taylor (trial host); Agrimm Technologies Ltd (Trichoderma seed treatment)

Key points

Trichoderma-treated seed resulted in:

- Colonisation of the ryegrass rootzone by *Trichoderma atroviride*.
- A significant reduction in root damage by *Gaeumannomyces graminis* var *tritici* (*Ggt*), the causal agent of take-all.
- Increased reproductive tiller number at mid-seed filling.
- A 4% seed yield increase in perennial ryegrass (associated with reduced dressing loss).

Background

A number of growers with irrigation have had re-occurring issues of light seed and large dressing losses in perennial ryegrass seed crops. Diagnostic assessments on some of these fields have shown an association with the root-rot pathogen *Gaeumannomyces graminis* var. *tritici* (*Ggt*) which causes ‘take-all’ in grasses and cereals. A pot study by Umar *et al.* (2019) demonstrated the potential for suppression of *Ggt* by *Trichoderma* spp. where a preliminary pot trial showed improved seed production of prairie grass when sown in soil known to be infested with *Ggt (Umar et al. 2021)*. In 2019-20, *Trichoderma* seed treatment reduced root damage from take-all but did not increase seed yield (Kandula *et al.* 2020).

The objectives of this study were to field-test a pasture bio-inoculant (PBI) to determine if *Trichoderma* seed treatment could reduce *Ggt* infection and increase seed yield, perhaps via a reduction in the amount of light seed, in a first-year perennial ryegrass seed crop.

Methods

Perennial ryegrass cv. Platform AR37 was drilled in 15 cm rows by the farmer on 24 March 2020 as part of a larger field for seed production. Seed was treated by Agrimm Technologies Ltd. with “pasture bio-inoculant” (PBI) which is a mixture of four isolates (LU132, LU140, LU584 and LU633) of *Trichoderma atroviride*. There were three blocks of *Trichoderma*-treated seed, each block the length of the field (440 m) and 8.4 m wide (two drill passes). Each block was separated by an untreated block, giving three replicates with two treatments. The field was irrigated and all management inputs were applied by the farmer as part of his normal seed crop management.

The field was sampled twice to assess the *Trichoderma* colonisation of the rhizosphere (area around the roots) by taking four soil cores (10 cm depth) per plot for *Ggt* assessment and a ryegrass dry matter assessment based on a 2.7 m^2 quadrat per plot. Reproductive and vegetative tillers pre-harvest were assessed from a 0.2 m^2 quadrat on 15 January 2021. The grower harvested each 0.3 hectare plot separately (5 February) and the field-dressed (FD) seed yield was determined with a weigh-wagon. A sub-sample was retained for seed cleaning. The FD seed was cleaned in a laboratory with sieves and blown in a Dakota seed blower to achieve a thousand seed weight (TSW) sample of >1.90 g. Statistical analysis was completed using Genstat 19 (VSN 2019).

Results and Discussion

Four months after sowing there was a high level of root and endophytic (i.e. growing inside) colonisation by the *Trichoderma* and a lower *Ggt* root disease severity score (Table 1). At eight months these differences were still distinct and dry matter yield was 15% higher in the PBI-treated ryegrass (Table 1). Pre-harvest these differences resulted in a 22% increase in reproductive tiller number in the PBI treatment and a small (4%) but significant seed yield increase (Table 2). The dressing loss was lower in the PBI treatment to achieve the same seed TSW.

Table 1. Number of colony forming units (CFU) present and percentage of root endophytic colonisation following treatment with *Trichoderma* pasture bio-inoculant (PBI) four or eight months after sowing of coated seed and the subsequent root disease severity and dry matter yield of perennial ryegrass cv. Platform grown in a *Gaeumannomyces graminis* var *tritici* (*Ggt*)-infected field on 24 March 2020 at Ashton, Mid-Canterbury.

Assessment	Assessment date	Treatment/score		Statistical significance[1]
		Untreated control	PBI	
PBI (CFU/g soil)	27/7/2020	243	16800	*
	23/11/2020	267	21400	*
Root endophytic colonisation (%)	27/7/2020	5	24	*
	23/11/2020	7	31	*
Ggt root score	27/7/2020	0.54	0.21	*
	23/11/2020	1	0.42	*
Dry matter production (kg/ha)	27/7/2020	1080	1190	NS
	23/11/2020[3]	1680	1940	*

[1] * indicates difference significant at p <0.05. NS, not significantly different. [2] *Ggt*, the casual pathogen of 'take-all', scores based on a visual scale of 0 (nil infection) to 5 (severe infection). [3] dry matter produced in one month following closing on 23 October 2020.

Table 2. Reproductive and vegetative tiller number along with seed yield parameters, of perennial ryegrass cv. Platform grown in a *Gaeumannomyces graminis* var *tritici* (*Ggt*)-infected field when treated with a *Trichoderma* pasture bio-inoculant (PBI). Sampling was completed 15 January 2021 and harvested on 5 February 2021 when grown near at Ashton, Mid Canterbury.

Assessment	Treatment/score		Statistical significance [1]
	Untreated control	PBI	
Reproductive tillers/m^2	1763	2156	*
Vegetative tiller /m^2	364	205	*
MD yield (kg/ha)	1745	1820	*
TSW (g)	1.97	1.98	NS
Dressing loss (%)	21	17	*

[1] * indicates difference significant at p <0.05. NS, not significantly different.

Summary

A seed coating of four *Trichoderma atroviride* isolates allowed successful colonisation of ryegrass roots. This reduced the incidence of *Ggt,* the causal agent of take-all disease. Dry matter production in the four weeks after closing was increased by 15% and reproductive tiller number by 22%, resulting in a 4% increase in seed yield associated with a reduction in dressing loss. The field trials with PBI are being repeated in 2021-22.

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Irrigation and fungicide programmes for management of disease in cocksfoot

Project code:	H19-03-01
Duration	Year 1 of 3
Authors	Owen Gibson and Phil Rolston (FAR)
Location	FAR Chertsey Arable Site, Chertsey, Canterbury
Funding	Seed Industry Research Centre (SIRC)
Acknowledgements	Mark Braithwaite (Plant Diagnostics) (disease assessments); NZ Arable (trial operators); Vantage (soil water monitoring)

Key Points

- Overhead irrigation had no influence on cocksfoot disease levels or seed yield.
- The addition of fungicides did not increase seed yield.
- Low disease pressure resulted in limited differences between treatments.

Background

Increasing disease pressure in cocksfoot (*Dactylis glomerata*) seed crops has been reported by growers in Mid-Canterbury, with symptoms of premature bleaching of the rachis causing premature crop senescence and a reduction in yield due to reduced seed weight. Previous research has shown no single disease causing the symptoms, suggesting a complex of diseases is involved (Rolston and Braithwaite, 2020).

The majority of cocksfoot in New Zealand is grown under overhead irrigation. It is postulated that overhead irrigation increases fungal and bacterial disease by spreading disease spores through water splash infecting nearby plants. The resulting extended period of leaf wetness may cause increased spread of diseases, especially bacterial diseases like *Pseudomonas*. These can be made worse by the subsequent water splash increasing the rate of infection from plant to plant.

The use of copper-based fungicides is becoming widespread in cocksfoot as a low-cost preventative measure, either by themselves or when mixed with a standard triazole/strobilurin fungicide programme to combat the onset of disease or severity without over-utilising the current fungicide chemistry. The trial tested the effect of overhead versus trickle irrigation direct to the soil with and without fungicides or copper to improve understanding of the epidemiology of this disease issue.

Methods

Four fungicide treatments were overlaid on two cultivars (Table 1) in a third-year stand of Cocksfoot (*Dactylis glomerata)*. The two cultivars were Savvy (PGGW) and Greenly II (SeedForce). The trial was a randomised block design with six blocks. Three blocks were irrigated with six overhead mechanical sprinklers per block, at an optimal working pressure of 2.5 bar, ensuring an 11 m spray radius with a resultant double overlap. The remaining three blocks were irrigated by trickle tape with four tapes laid between each drilled row within the plot. Pressure was reduced (to 1.1 bar) with inline pressure reducers to maintain a reliable working pressure. Irrigation was applied weekly to maintain soil moisture holding capacity at 50% or higher. The trial was irrigated on nine occasions with a total of 255 mm water applied. Soil moisture was monitored weekly by Vantage New Zealand with neutron probes; readings were received at the start of each week and water applied with the use of weather forecasts to inform application rates. Plots were 10 m by 1.7 m with three replicates. Fungicides used in the trial were: Proline® (a.i. 250 g/L prothioconazole, Group 3), Amistar® (a.i. 250 g/L azoxystrobin, Group 11), Seguris Flexi® (a.i. 125 g/L isoprazam, Group 7) and Tri-Base Blue® (a.i. 190 g/L copper as tribasic copper sulphate) (Table 1).

The trial was sown on 2 March 2018 with a belted cone research plot drill with 5-disc coulters at 30 cm spacings. Disease and green leaf area were assessed on 30 December 2020 by collecting a handful of stems from three random spots within each plot and delivering to Plant Diagnostics for disease scoring and identification. The trial was windrowed on 8 January with a modified John Deere windrower and harvested with a Sampo plot combine on 18 January 2021. The trial received 80 kg spring nitrogen (N) in two applications: 40 kg N on 25 March as SustaiN® N followed by a further application of 40 kg N on 4 May as Nrich SOA (20.5% nitrogen + 23% sulphur). 150 g Hussar® (50 g/kg iodosulfuron-methyl-sodium and 150 g/kg mefenpyr-diethyl (safener), Group 2 herbicide) + 1 L Partner® (vegetable oil polymer) was applied for ryegrass control on 7 May, followed by two applications of atrazine (Group 5) plus diuron (Group 5) for volunteer cocksfoot control, applied on 2 June (1 L Atraflow™, 500 g/L atrazine plus 1 kg Karmex® DF - 800 g/kg diuron) and 3 July (1 L Atraflow™ plus 0.5 kg Karmex® DF). A total of 120 kg spring N was applied in three applications of 40 kg N as SustaiN® N on 31 August, 12 October and 6 November. Plant growth regulator was applied at growth stage (GS) 32 as 0.4 L Moddus® Evo (250 g/L trinexapac-ethyl) + 1.5 L Cycocel® (750 g/L chlormequat chloride) on 13 October.

Table 1: Treatment list for cocksfoot irrigation x fungicide trial at Chertsey, Mid Canterbury in the 2020/21 growing season.

Tmt No.	Fungicide treatments (L/ha), application dates and crop growth stages at application			
	2nd PGR Timing (22.10.20)	**Head Emergence (23.11.20)**	**Flowing (9.12.20)**	**+ 14 Days (23.12.20)**
1	Nil	Nil	Nil	Nil
2	Proline® (0.4)	Proline® (0.4) + Amistar® (0.75)	Proline® (0.4) + Seguris Flexi® (0.6)	Proline® (0.4) + Seguris Flexi® (0.6)
3	Tri-Base Blue® (3.0)	Tri-Blue Blue® (3.0)	Tri-Base Blue® (3.0)	Tri-Blue Blue® (3.0)
4	Proline® (0.4) + Tri-Base Blue® (3.0)	Proline® (0.4) + Amistar® (0.75) + Tri-Base Blue® (3.0)	Proline® (0.4) + Seguris Flexi® (0.6) + Tri-Base Blue® (3.0)	Proline® (0.4) + Seguris Flexi® (0.6) + Tri-Base Blue® (3.0)

Proline® (a.i. 250 g/L prothioconazole, Group 3), Amistar® (a.i. 250 g/L azoxystrobin, Group 11), Seguris Flexi® (a.i. 125 g/L isoprazam, Group 7) and Tri-Base Blue® (a.i. 190 g/L copper as tribasic copper sulphate)

Results and Discussion

In 2020-21, rainfall was mostly below average, with the exceptions of June and November, with near average temperatures and solar radiation through grain fill. As a result, there was a low level of reported bacterial bleaching and an absence of any observable fungal disease.

There was a small but significant difference in seed yield between the two cultivars with cv. Savvy producing greater yields than Greenly II under both irrigation regimes (Table 2). Cultivar Savvy also had higher seed yields than cv. Greenly in the previous two seasons at the same trial site in plant growth regulator (PGR) trials (Harrison *et. al.* 2020). There was no evidence that this yield difference was caused by fungal or bacterial disease (Table 3).

In this trial, no significant difference in disease or yield was observed between overhead and trickle tape irrigation ($p=0.752$). The average yield for overhead irrigation was 1010 kg/ha (cv. Savvy, 1070 kg/ha; cv. Greenly II, 960 kg/ha), whereas trickle tape irrigation yielded an average of 1000 kg/ha (cv. Savvy, 1060 kg/ha; cv. Greenly II, 940 kg/ha).

In this trial, the application of copper sulphate, either solo or as a mix, did not decrease the bacterial disease levels (4-17%, Table 3) compared with the untreated control (Table 3). There was no significant difference in yield compared with the untreated control. In both the overhead and trickle-tape treatments, fungicide treatment significantly increased Green leaf area (GLA) compared with the untreated control (P value < 0.001, Table 4). However, the degree of green leaf area did not relate to a yield increase. It is possible that trial conditions were not conducive to the development of recent disease symptoms and yield losses in cocksfoot seed crops in the Canterbury area.

Table 2. Seed yields (kg/ha) for two cocksfoot cultivars, ‘Savvy’ and ‘Greenly II’, grown under two different irrigation systems at Chertsey, Mid-Canterbury in the 2020-21 growing season.

Fungicide Treatment	**Overhead Irrigation**			**Trickle Tape Irrigation**		
	Savvy	**Greenly II**	**Fungicide mean**	**Savvy**	**Greenly II**	**Fungicide mean**
1	1020	910	960	1070	930	1000
2	1010	940	970	970	860	910
3	1120	990	1050	1150	935	1040
4	1100	990	1050	1030	1050	1040
Cultivar mean	**1070**	**960**	**1010**	**1060**	**940**	**1000**
P value	**0.008**		**0.96**	**0.039**		**0.46**
LSD (p=0.05)	**76**			**107**		

Table 3. Cocksfoot flowering stems showing bacterial bleaching (%) for two cocksfoot cultivars, ‘Savvy’ and ‘Greenly II’, on 30 December 2020 at Chertsey in Mid-Canterbury in the 2020-21 growing season.

Fungicide Treatment	**Overhead Irrigation**			**Trickle Tape Irrigation**		
	Bacterial Disease		**Fungicide**	**Bacterial Disease**		**Fungicide**
	Savvy	**Greenly II**	**Mean**	**Savvy**	**Greenly II**	**Mean**
1	10	16	13	12	22	17
2	4	9	7	5	7	6
3	14	6	10	15	16	16
4	7	12	9	6	5	6
Cultivar mean	**9**	**11**	**10**	**10**	**12**	**11**
P value	**0.337**		**0.57**	**0.579**		**0.018**
LSD (p=0.05)	**13**					**9**

Table 4. Green leaf area (GLA) (%) for two cocksfoot cultivars, ‘Savvy’ and ‘Greenly II’, on 30 December 2020 at Chertsey in Mid-Canterbury in the 2020-21 growing season.

Fungicide Treatment	**Overhead Irrigation**			**Trickle Tape Irrigation**		
	GLA		**Fungicide**	**GLA**		**Fungicide**
	Savvy	**Greenly II**	**Mean**	**Savvy**	**Greenly II**	**Mean**
1	24	37	31	12	34	23
2	78	82	80	77	80	79
3	12	57	34	21	46	33
4	72	50	61	53	77	65
Cultivar mean	**47**	**56**	**51**	**41**	**59**	**50**
P value	**0.002**		**<0.001**	**0.31**		**<0.001**
LSD (p=0.05)	**21**		**15**			**14**

Summary

Irrigation method and fungicide programme had no effect on disease levels or ultimately seed yield in a cocksfoot seed crop in Mid-Canterbury in the 2020-21 season. In particular, the limited pressure from bacterial disease resulted in the crops treated with copper yielding similar to the untreated control. The use of copper sulphate is becoming increasingly popular as a cheap biocide to control bacterial diseases in cocksfoot seed crops and to reduce risk from seed yield losses. These data suggest seasonal conditions will determine the return-on investment.

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Brown rust and stem rust control in ryegrass seed crops in South Canterbury

Project code	H19-03-02
Duration	Year 1 of 1
Authors	Ben Harvey, Richard Chynoweth and Phil Rolston (FAR)
Location	Saint Andrews, South Canterbury (44°31'35.05"S, 171° 8'42.95"E)
Funding	Seed Industry Research Centre (SIRC)
Acknowledgements	Richard Porter, Saint Andrews (trial host); NZ Arable (trials operator); Mark Braithwaite, Plant Diagnostics

Key Points

- Brown rust (*Puccinia recondita*) appeared to have little to no effect on yield in a perennial ryegrass (*Lolium perenne)* seed crop.
- The application of early fungicide to seed crops of perennial ryegrass helped control stem rust (*Puccinia graminae*), increasing seed yields.
- There was a strong negative correlation between disease incidence and seed yield.
- The economic benefits were marginal.

Background

Stem rust disease, caused by *Puccinia graminae*, can result in seed yield losses of 20 to 50% in perennial ryegrass (*Lolium perenne*) seed crops. A related disease, *Puccinia recondita* (brown rust or leaf rust) is more commonly found on wheat, but has been observed on perennial ryegrass. Little information exists on the effect of *P. recondita* on ryegrass or on its control.

This study was specifically interested in investigating how brown rust affects perennial ryegrass seed crops. The key questions were:

1. Do early outbreaks of brown rust in a perennial ryegrass seed crop affect seed yield?
2. Can pre-GS 32 fungicide applications to ryegrass seed crops, infected with brown rust, improve both control of the disease and seed yield?
3. Do earlier applications of fungicide have an effect on stem rust later in the season?

Methods

A trial was designed to gather information on the effectiveness of a range of fungicides in a South Canterbury ryegrass seed crop during the 2020-2021 growing season on brown rust and stem rust.

The trial was established in an irrigated, European diploid turf-type perennial ryegrass (cv. Syringa) near St Andrews, South Canterbury, where an early outbreak of brown rust had been observed. The paddock and all inputs except the early fungicide treatment and plant growth regulator (PGR) were managed by the grower. Post Moddus® Evo (active ingredient (a.i.) 250 g/L trinexapac-ethyl) PGR application, the trial received the same inputs as the rest of the paddock. This included the normal fungicide programme as applied by the grower, which is shown in Table 1. The plots were 11 x 3.3 m with seven treatments replicated four times in a randomized block design. Moddus® Evo PGR was applied at 1.3 L/ha (325 g a.i./ha) on 12 November 2020. The fungicides evaluated were Proline® (a.i. 250 g/L prothioconazole, Group 3), Opus® (a.i. 125 g/L epoxiconazole, Group 3) and Comet (a.i. 250 g/L pyraclostrobin, Group 11). The early fungicide applications were made on 29 October 2020 (GS 31), while one treatment received fungicide with the Moddus® application (GS 32, Table 2).

The level of brown rust infection was assessed in the untreated control on 10 November. Full disease assessments were carried out on 17 November 2020 and 8 January 2021. In the first assessment, ten stems were randomly selected from each plot, and every leaf from each stem was visually scored for the severity of leaf rust. In the second assessment, 25 stems were randomly selected from each plot, and visually assessed for presence or absence of stem rust; lesions per stem were counted where stem rust was present. Green leaf area percentage (GLA%) of the flag leaf was visually estimated on the same stems. The trial was windrowed on 22 January 2021 and combine-harvested on 27 January 2021. The field dressed sample was dressed to a First-Generation Seed Certification Standard.

Statistical analysis was by general analysis of variance (ANOVA), using Genstat® 19th edition (VSN International Ltd, UK).

Results and Discussion

Brown rust control

On 10 November, 50% of leaves had brown rust present with an average leaf area covered of 26% (±5 % SEM). A full disease assessment on November 17, following fungicide applications in late October/early November, found that the incidence of brown rust had decreased in all treatments. In the untreated control, incidence had reduced to 2% and there were no statistical differences among treatments. The disease assessment carried out in early January found no evidence of brown rust, even in the untreated control, although stem rust was present (see below). Seed yield differences among treatments were minimal, although there seemed to be some benefit to the early fungicide application (Table 2). Since brown rust appeared to be controlled by the grower's usual programme, it is likely that these yield differences were due to increased stem rust control.

Stem rust control

The seed yield differences were relatively small while the Margin-over-Cost (MoC) analysis (Table 2) showed no difference between treatments. The observed seed yield differences were related to decreases in stem rust incidence (Figure 1). Stem rust incidence was reduced in all treatments except when Opus® (500 mL/ha) was applied. There was no effect on green leaf area.

The highest yielding fungicide treatment was the double application of Proline® (0.4 L/ha), which resulted in both the lowest disease incidence, and a 15% increase in seed yield compared with the untreated control. There was no difference between this treatment and a single full rate Proline® (0.8 L/ha) or Opus® (1 L/ha). However, the two single half rate applications of Proline® and Opus® did have significantly lower seed yields than the double rate of Proline® (0.8 L/ha). Turf ryegrasses are highly susceptible to seed yield losses from stem rust, and as such normally receive an extensive fungicide programme. These results suggest that this programme also controlled early outbreaks of brown rust in this instance.

Summary

This trial investigated how the application of early fungicide treatments to a perennial ryegrass seed crop, infected with brown rust, affected incidence of the disease and hence, seed yield. Brown rust disappeared from the trial under the grower's normal fungicide regime. Early fungicide application did provide slightly improved control of stem rust, leading to a small increase in seed yield in this trial, however the benefits were modest and not highly significant.

Table 1. Fungicide treatments as applied to the trial by the grower.

Fungicide	Rate (mL/ha)	Date Applied
Proline ®	400	24 November 2020
Seguris Flexi®	500	
Proline®	400	7 December 2020
Seguris Flexi®	300	
Cyproconazole	100	
Epoxiconazole	350	21 December 2020
Azoxystrobin	400	
Cyproconazole	100	

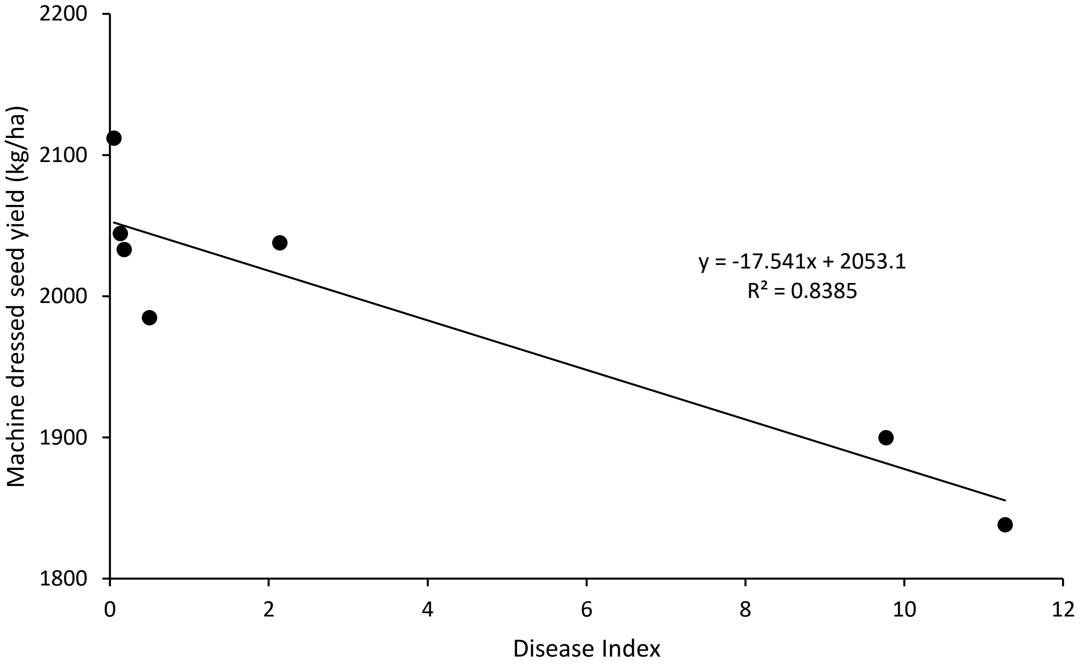

Figure 1. Relationship between stem rust disease index and mean seed yield in a perennial ryegrass, cultivar 'Syringa', seed crop in South Canterbury in the 2020-21 growing season. Note: Disease index is equal to the average number of pustules per stem multiplied by the proportion of stems that are infected.

Table 2. Seed yield and stem rust infection at harvest of turf perennial ryegrass, cultivar Syringa, treated with seven fungicide programmes and grown under irrigation near Saint Andrews, Canterbury in the 2020-21 growing season.

Treatment No.	**Fungicide treatments, rates and application dates**		**Seed Yield (kg/ha)**	**Disease Index[2]**	**Green Leaf Area (%)**	**Margin over Fungicide Cost ($/ha)**
	29 October	**12 November (PGR, GS 32)[1]**				
1	-	-	1840 a	11.3 b	22	0 a
2	0.4 L/ha Proline® [3]	-	1990 ab	0.5 a	36	258 abc
3	0.8 L/ha Proline®	-	2040 bc	0.1 a	31	349 abc
4	0.5 L/ha Opus®	-	1900 ab	9.8 b	26	97 ab
5	1 L/ha Opus®	-	2040 bc	2.1 a	22	378 bc
6	1 L/ha Opus® + 0.8 L/ha Comet®	-	2030 bc	0.2 a	27	314 abc
7	0.4 L/ha Proline®	0.4 L/ha Proline®	2110 bc	0.1 a	23	495 bc
		LSD (p=0.05)	**167**	**5.1**	**NS**	**NS**
		P value	**0.041**	**<0.001**	**0.49**	**0.121**

Note: Yield values followed by the same letter are not significantly different from each other. Margin-over-Fungicide Cost calculations are based on the contract ryegrass seed price of $2.25/kg. [1]GS = growth stage. [2]Disease Index is equal to the average number of pustules per stem multiplied by the proportion of stems that are infected. [3] Proline® (a.i. 250 g/L prothioconazole, Group 3); Opus® (a.i. 125 g/L epoxiconazole, Group 3); Comet (a.i. 250 g/L pyraclostrobin, Group 11). NS = not significant.

Stem rust in different ryegrass seed crop cultivars

Project code H19-03

Duration Year 3 of 4

Authors Nicholas Davies (AgResearch) and Phil Rolston (FAR)

Location PGG Wrightson Seeds, Kimihia Research Station, Lincoln

Funding SIRC (Seed Industry Research Centre)

Acknowledgements Richard Sim, Murry Kelly, Will Mitchell, Louise Carpenter (PGGW Seeds)

Key points

- New Zealand bred forage cultivars showed a higher tolerance to stem rust than turf and northern hemisphere cultivars.
- An exponential relationship between infected tillers and total pustules was confirmed for reproductive organs.
- A substantial proportion of tillers were infected before pustule counts rapidly increased, indicating stem rust disease spreads between tillers and then within tillers as infection worsens.
- Differences in stem rust tolerance among cultivars is likely to be quantifiable.

Background

Puccinia graminae is a fungus which infects grasses causing the disease commonly known as stem rust. It attacks stems and heads and cuts off nutrient supply to seeds, reducing seed fill. Yield losses are seasonally dependent and previous FAR trials have shown yield reductions of 20-50+%. New Zealand bred forages appear to be more tolerant to stem rust infection than those from northern hemisphere and turf cultivars.

There are effective fungicide options for managing stem rust, however they need to be applied before the infection becomes obvious. Two challenges exist because of this:

1. How to identify and treat cultivars depending on their genetic tolerance?
2. How to identify when an infection first occurs to optimise fungicide inputs?

This project has been adapting a model from the USDA and Oregon State University (Pfender et al. 2015) to predict stem rust infection over the last two years (Davies et al. 2020). The 2020-21 trial was used to improve our understanding of how to predict the start of stem rust infections and to quantify differences in cultivar susceptibility, two things the model is not well suited to. Going forward, the information gained will be used to enhance the stem rust prediction model to help provide guidance on risk.

Methods

The PGG Wrightson Seeds team run an internal trial at the Kimihia Research Station, located near Lincoln, with cultivars which they use to track crop development and disease susceptibility. This information is then provided to the Arable Rep team to support in-field agronomic decisions. No fungicides were applied to the trial. Nine cultivars were selected within this trial, broadly representing turf and forage from New Zealand, North America, and Europe and with a range of heading dates from 0 (Nui) to +35 days. Note, for reasons of commercial sensitivity, other than Nui, the cultivar names are not used, but some relevant properties of the cultivars are given (Table 1).

The cultivars were replicated twice (but not randomised), and each cultivar was represented by two isolated rows next to each other, approximately 2 m long and one plant wide. Starting in October, the rows of selected cultivars were observed for stem rust. Once a pustule was found in the trial, weekly sampling commenced on 25 tillers per row (50 tillers per cultivar), randomly selected by cutting roughly a handful at ground level at three random positions in each row. For an infection rate of 1 tiller in 100, a 50-tiller sample gives 40% probability of finding an infected tiller. An infection rate of 6 infected tillers in 100 gives a 95% probability of finding at least one infected tiller within the collection of 50 tillers.

The bundles were mixed on a bench, then tillers were taken at random from the pile and the number of pustules on the stem, head, and leaves were recorded. On the 15 January 2021 the trial was topped to remove the reproductive heads. After topping, vegetative tillers were collected at periods between once-a-week and once-a-month depending on the weather (low growth of fungi in winter, so less sampling).

Table 1. Details of the cultivars used in the trial at Lincoln, 2020-21.

Cultivar	Heading date (Nui = 0)	Type	Origin
F1 (Nui)	0	Forage	New Zealand
F2	+20	Forage	New Zealand
F3	+8	Forage	European
T1	+11	Turf	New Zealand
T2	+12	Turf	New Zealand
T3	+18	Turf	New Zealand
T4	+11	Turf	European
T5	+20	Turf	North America
T6	+35	Turf	European

A Bayesian mixed model was used to fit logistic curves to total pustule counts and percent infected tillers. Logistic curves are parameterised by three parameters, which control the start date of visual infection, the rate of increase, the end date, and the date were the logistic curve flattens. The rate of increase in infection can be seen as a measure of tolerance to the disease, i.e. once there is infection, how quickly can it spread in a given cultivar. The start date is the date at which the disease reaches a level of infection which can be detected. The end date is where maximum infection is reached, shown by the curve flattening. Having these parameters lets us investigate the relationships between cultivar features such as heading date, type and origin with stem rust tolerance and infection onset. The following is an example of a logistic equation, where *a*, *b* and *c* are cultivar specific parameters and *t* is time. The full model is not presented here, but the model incorporates all cultivars into a single analysis which fits these logistic curves to each cultivar.

$$Infection = \frac{\mathrm{c}}{1 + e^{\left(\frac{b-t}{a}\right)}}$$

Results and Discussion

Both the percentage of infected tillers and the total number of pustules per 100 stems followed a logistic curve (Figures 1 and 2). Cultivars showed differences in the rate of infection increase, as well as the number of pustules present before topping. All cultivars reached near 100% of tillers infected (Figure 1), however at topping some of the turf grasses had more than double the number of pustules as Nui (Figure 2). Although cultivars reached near 100% of tillers infected, the average pustules per tiller differed. Whether this resulted in a difference in seed yield between cultivars is not known as the plots were not harvested.

The differences in curve steepness among cultivars indicates the potential to classify cultivars into risk categories quantitively (with more data). It is interesting to note that the three forage cultivars in the trial had the lowest gradients, indicating some tolerance to rust which is not present in the turf types. Whether this is an artefact of the chosen cultivars or a more generalisable correlation requires further examination.

A strong relationship (r=0.97) exists between the log of the number of pustules and the percent of infected tillers, which shows a substantial proportion of tillers becoming infected before pustule counts rapidly increase. This indicates the disease spreads between tillers and then within tillers as infection worsens. The percentage of infected tillers approaches 100 for all cultivars, while the total pustules at topping for Nui and another New Zealand forage (heading date of Nui +20) were approximately half that of the worst affected turf types. The slower spread implies tolerance within those cultivars. In other fungicide trials where only a single cultivar was used, the percentage of infected tillers at harvest often correlates with yield loss. It is unknown if this trend will be evident between cultivars.

The Pearson correlation between parameter *a* (in Equation 1) and heading date is -0.84 when considering the number of pustules (later heading dates correlate with steeper curves). However, the correlation was weak between parameter *a* and the percent of infected tillers (-0.22), indicating that while advanced infections (multiple pustules per tiller) have a strong relationship with heading date, early infection has only a weak relationship. This may be an indication that infection early in an epidemic is largely driven by air transport of spores, whereas the exponential explosion is driven by the contact spread from sheath infection.

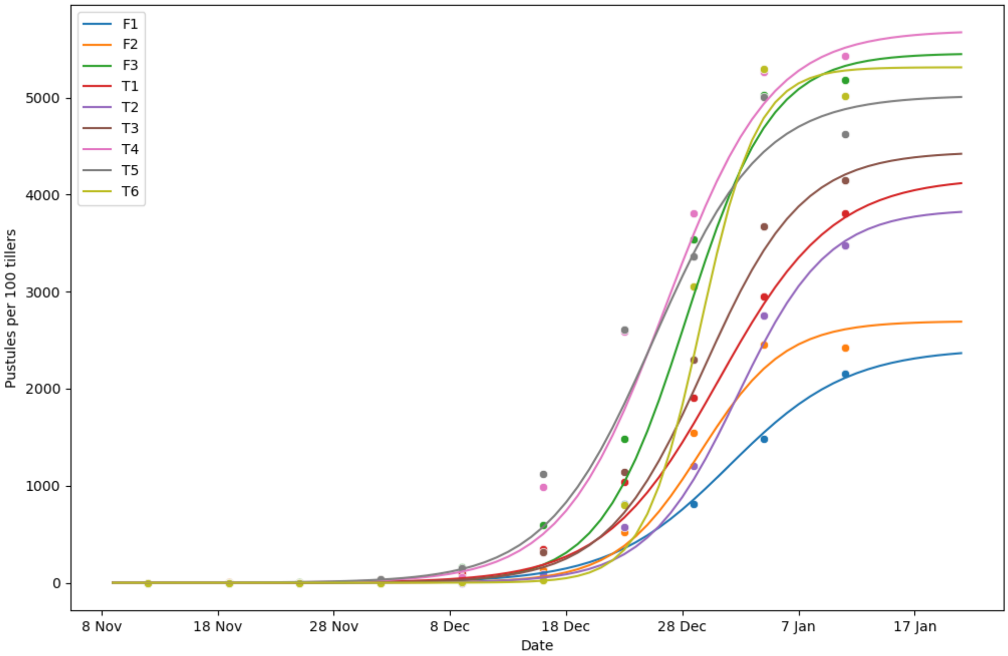

Figure 1. Percentage of tillers infected with stem rust during the 2020-21 season for nine perennial ryegrass cultivars when grown near Lincoln, using fitted curves. F = Forage, T = Turf. Note the New Zealand forages with the lowest slope (F1 – Nui and F2), and the very late heading turf with a high slope (T4, T5 and T6).

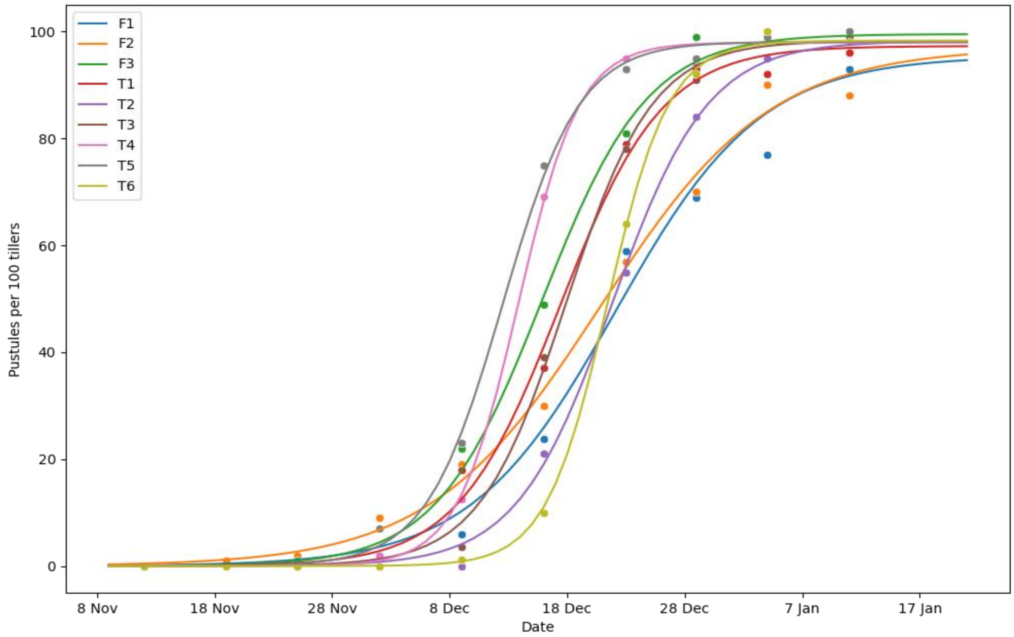

Figure 2. Number of stem rust pustules per 100 tillers on nine cultivars of perennial ryegrass grown near Lincoln in the 2020-21 growing season (using fitted curves). Note the two New Zealand forages (F1 = Nui and F2) have a lower slope and maximum.

Summary

There are indications that cultivars, type (turf or forage), origin (New Zealand or Northern Hemisphere) and heading date influence stem rust infection, although the trial was not large enough to provide reliable statistics. With further trials, it may be possible to quantify stem rust resistance/tolerance of cultivars by using the parameters of the logistic curves fitted to observed data. The development of a method for fitting observed data by cultivar is another step toward the development of a predictive model for stem rust infection (Pfender et al. 2015).

References

Davies, N, Chynoweth, R and Rolston, P (2020). Stem rust control in turf ryegrass seed crops and development of a prediction model. *SIRC Research Results 2019/2020*: Pp 10-12.

Pfender, W, F, Coop, L, B, Seguin, S, G, Mellbye, M, E, Gingrich, G, A and Silberstein, T, B (2015). Evaluation of the ryegrass stem rust model STEMRUST_G and its implementation as a decision aid. *Phytopathology* 105: 35-44.

White clover harvest management

Project Code	H19-07
Duration	Year 4 of 5
Authors	Owen Gibson, Phil Rolston (FAR)
Location	Lincoln, Mid Canterbury; (GPS -43.618201, 172.450007)
Funding	Seed Industry Research Centre (SIRC)

Acknowledgements: Chris Morrish (trial host); NZ Arable (trial operator)

Key Points

- Buster® (a.i. 200 g/L glufosinate-ammonium, Group 10), Granstar® (a.i. 750 g/kg tribenuron-methyl, Group 2) or glyphosate (Group 9) are options for desiccation of white clover crops, especially where crops are bulky or where re-growth from a Reglone® (a.i. 200 g/L diquat, Group 22) treatment is an issue, under damp conditions.
- There was limited post-harvest re-growth from Buster®, Granstar® and glyphosate treatments; this becomes an issue if grazing or second year crops are important.
- GreenMan™ treatments yielded comparable to Reglone® treatments.
- White clover re-grows quickly after application of GreenMan™ resulting in less dry down than the equivalent Reglone® treatments.
- Windrowing resulted in a 20% decrease in seed yield.

Background

In New Zealand, most white clover seed crops are direct harvested after desiccation. The chemical diquat is heavily relied upon to desiccate the crop before harvest and enable direct heading. In parts of Europe diquat has been banned with zero residues permitted. This research was established to examine alternatives for the New Zealand system which often includes post-harvest lamb grazing.

In a white clover crop, Reglone® (active ingredient (a.i.) 200 g/L diquat, Group 22) as either a single or double application does not always ensure adequate dry down, especially in bulky crops in wet seasons when penetration is difficult to achieve. MCPA (2-methyl-4-chlorophenoxyacetic acid, Group 1), traditionally applied as a pre-desiccant treatment may increase the difficulty in treating the crop as it twists the clover plants and collapses the canopy.

Many New Zealand farms utilise the post-harvest re-growth from white clover seed crops for lamb grazing. This means any diquat substitute must have good crop dry-down properties and allow re-growth for the livestock system. FAR has evaluated alternative desiccants in a range of trials from the last four years to investigate pre-desiccants and alternatives to diquat. Greenman™ (a.i. 650 g/L fatty acids, Group 0) is a promising alternative to Reglone® but is effective on clover only at greater concentrations (8% v/v) than those recommended (2-4% v/v). However, Greenman-treated clover starts to re-grow six days after application, ultimately requiring a follow up application to ensure adequate desiccation. This trial evaluated potential alternatives to diquat: Buster® (a.i. 200 g/L glufosinate-ammonium, Group 10), Granstar® (a.i. 750 g/kg tribenuron-methyl, Group 2), Glyphosate (Weedmaster®TS540 – a.i. 540 g/L glyphosate, Group 9) and windrowing treatments in conjunction with GreenMan™ and Reglone®.

Methods

The trial was established in a white clover seed crop, cultivar Huia near Broadfields, Canterbury, prior to desiccation. Irrigation was applied with a Briggs rotating irrigator with two applications: 30 mm on 24 October 2020 and 25 mm on 18 December 2020. All paddock management was as per the host farmer throughout the season.

The trial consisted of 13 treatments with four replicates as a randomized block design. Each plot was 2 x 11 m. Treatments were applied by a backpack sprayer with an electric pressure pump suppling a 2 m spray boom fitted with 6 x 110 015xr tee jet nozzles delivering 250 L water/ha, at 210 kpa pressure creating a very fine spray droplet.

The desiccant rate and date of application are listed in Table 1. Crop burnout was visually assessed at seven-day intervals and dry matter percentage from a 0.3 m^2 quadrat, three days before harvest. The windrow plots were cut with a modified John Deere plot windrower on 27 February 2021 or 4 March 2021 (Table 1). All plots were harvested with a Wintersteiger nursery master plot combine on 5 March 2021. The seed was machine-dressed to a First-Generation Seed Certification standard. Seed germination tests were completed by NZ Seed Lab on 7 July using a 4-day pre-germination 5°C chilling and a 10-day final count. The germination was calculated as the hard seed + germinated seed. The farmer desiccated the paddock with a pre-desiccant of 1.5 L/ha Agritone® (MCPA) followed by two treatments of 3 L/ha Reglone® (diquat) + 250 mL/ha Du Wett® (organosilicone) on 19 February, 25 February and 28 February 2021, respectively.

The trial area was fenced off directly after harvest before the rest of the paddock was grazed by sheep. White clover re-growth was scored visually with three scoring times (12, 19, 26 and 39 days after harvest) and on 13 April 2021 dry matter re-growth was assessed from quadrat cuts.

Results and Discussion

There was no difference in seed yield between the chemical desiccation treatments (Table 1). All desiccation treatments yielded significantly (P value = 0.01) greater than the windrow treatments. The windrow harvest treatments resulted in a 22% decrease in seed yield compared to all chemical desiccation treatments. This was consistent with the trial in 2019-20 where windrowing resulted in significantly lower yields (Chynoweth *et al.* 2020). Seed germination averaged 95% and there was no difference among treatments (data not shown).

GreenMan™ was the only product to provide rapid brownout, along with comparable seed yields and re-growth to Reglone® (Table 1). GreenMan™ produced relatively fast brown out following application but also greened up quickly with consistently higher pre-harvest moisture content compared with Reglone® (Figure 1). This means that GreenMan™ may require a follow up application, especially in years with wet harvest conditions. The addition of a pre-desiccant treatment had little effect on moisture content of GreenMan™ treatments (Table 1).

There was a marked decrease in post-harvest clover re-growth when Buster (64 kg/ha DM), Granstar® (267 kg/ha DM) and Roundup + Pulse (358 kg/ha DM) were used as a pre-desiccant while all other treatments produced the same re-growth.

Summary

GreenMan™ offers an alternative to Reglone® but may require a second application if the crop is bulky or harvest is delayed. However, GreenMan™ is a very expensive treatment, costing at least $1,200/ha at current prices. In this trial, a pre-desiccation MCPA treatment did not increase seed yield or dry down by “opening” the clover canopy for better chemical coverage. Windrowing white clover may be a good option during periods of less than ideal harvest conditions when chemical desiccation is ineffective. However, this does come with an increased yield loss, as seen in previous trials (Chynoweth *et al*. 2020).

Reference

Chynoweth, R, Washington, H, Gunnarsson, M, and Rolston, R (2020). Desiccation options for white clover seed harvest. *SIRC Research Results 2019/20*. Pp 20-24.

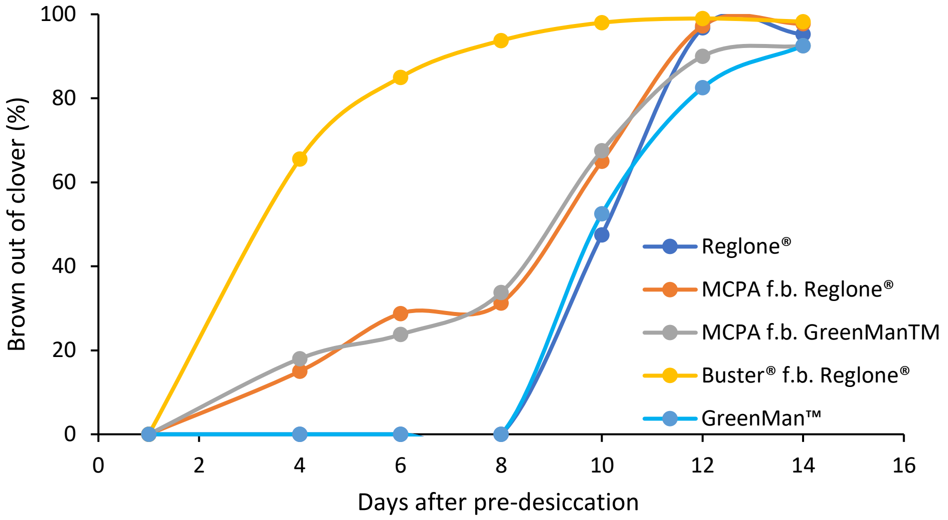

Figure 1. Percentage brown-out (necrosis) of white clover cultivar Huia, expressed in days after treatment following various methods of crop desiccation when grown near Lincoln in the 2020-2021 season. Note: all Reglone® and GreenMan^{TM} treatments were applied on Day 8.

Table 1. Seed yield of 'Huia' white clover, pre-harvest moisture content and post-harvest dry matter following various methods of crop desiccation when grown near Lincoln in the 2020-21 growing season.

Treatment No.	**Product, rate and timing of application[1,2]**				**Seed yield (kg/ha)**	**Pre-harvest moisture (%)**	**Post-harvest DM (kg/ha)**
	19 February	**27 February**	**3 March**	**4 March**			
1	-	Reglone® (4 L/ha)	-	-	587 b	25	870
2	Agritone® (2 L/ha)	Reglone® (4 L/ha)	-	-	596 b	28	950
3	Agritone® (2 L/ha)	GreenMan™ (8%)	-	-	590 b	35	820
4	Buster (5 L/ha)	Reglone® (4 L/ha)	-	-	604 b	24	60
5	-	GreenMan™ (8%)	-	-	593 b	31	790
6	Granstar 40 g	GreenMan™ (8%)	-	-	603 b	30	270
7	Agritone® (2 L/ha) + fish oil	GreenMan™ (8%) + fish oil	-	-	615 b	33	900
8	Weedmaster®TS540 (3 L/ha)	Reglone® (4 L/ha)	-	-	580 b	22	360
9	Reglone® (2 L/ha)	Reglone® (4 L/ha)	-	-	622 b	26	800
10	-	Reglone® (3 L/ha)	-	Windrow	452 a	23	1100
11	-	GreenMan™ (8%)	-	Windrow	476 a	27	860
12	-	Windrow	-	-	461 a	14	710
13	-	Reglone® (3 L/ha)	Reglone® (2 L/ha)	-	576 b	26	900
				LSD (p=0.05)	**72**	**6**	**295**
				P value	**<0.001**	**<0.001**	**<0.001**

Note: Yellow indicates the treatments that produced the greatest seed yield or post-harvest dry matter, or lowest moisture content. Yields with the same letter are not significantly different. [1]All product applied with additives as per label recommendations. [2]Buster® (a.i. 200 g/L glufosinate-ammonium, Group 10); Granstar® (a.i. 750 g/kg tribenuron methyl, Group 2), Weedmaster®TS540 (a.i. 540 g/L glyphosate, Group 9); Reglone® (a.i. 200 g/L diquat – Group 22).

Tolerance of second-year cocksfoot cultivars to different grass weed herbicide programmes

Project H19-11

Authors Phil Rolston and Richard Chynoweth (FAR)

Duration Year 3 of 3

Location Chertsey, Mid Canterbury

Funding Seed Industry Research Centre (SIRC)

Acknowledgements Pasture First (trial operator)

Key points

- No cultivar by herbicide interaction was detected in 12 cocksfoot cultivars grown as second-year crops and treated with one of 11 herbicide programmes.
- A 100 % control of perennial and annual ryegrass, and hairgrass was achieved in all treatments, with the exception of Hussar®, which had no activity on hairgrass
- Karmex® (a.i. 800 g/kg diuron, Group 5 herbicide) and Nu-Trazine™ 900DF (a.i. 900 g/L atrazine, Group 5), commonly used for grass weed management in cocksfoot, reduced cocksfoot seed head numbers in some, but not all, treatments.
- Kerb™ (a.i. 500 g/L propyzamide, Group 3) offered an option for mid-winter grass weed control as part of a sequence of herbicide treatments.
- Foxtrot® and Stratos™ (herbicide Groups 1 and 0, respectively) could be used in conjunction with the primary herbicides to control wild oat control in spring.

Background

The area of cocksfoot seed production in New Zealand increased rapidly over the five years prior to 2019, with many new cultivars being multiplied for re-export. Weeds in established cocksfoot seed crops include volunteer seedling cocksfoot, annual or perennial ryegrass, *Poa annua*, hairgrass (*Vulpia* sp.) and wild oats (*Avena fatua*). Two previous trials were conducted on 11 cocksfoot cultivars at Chertsey in both the first and second year after sowing (Rolston et al. 2019 and 2020).

In second-year crops, growers commonly use atrazine (active ingredient (a.i.) 900 g/L atrazine, herbicide mode-of-action (MOA) Group 5) and Karmex® (a.i. 800 g/kg diuron, Group 5) and/or Hussar® (a.i. 50 g/kg iodosulfuron-methyl-sodium, Group 2). In the previous trials, Kerb™ (a.i. 500 g/L propyzamide, Group 3) showed promise for grass weed control in cocksfoot using a different MoA with good crop tolerance.

A number of other herbicides (e.g. Alion®, Goal™, Sencor®, Othello®, Sakura®) used for grass weed control in other crops might offer control options in established second-year crops. However, growers lack information on the crop safety of these and other herbicides for the range of cultivars now being grown.

The aim of this trial was to evaluate tolerance across a range of cultivars from both continental (standard) and Mediterranean (which are more winter active) genetics to a number of herbicides with potential to control grass, broadleaf and wild oat weeds.

Methods

Twelve cocksfoot cultivars, including three Mediterranean types (‘Kasbah’, ‘Grasslands Kaha’ and ‘Howlong’; Table 1), were sown as individual rows in early March 2019, with 50 cm between rows. In addition, there was a row of perennial ryegrass (cultivar (cv.) Base), annual ryegrass (cv. Hogan) and hairgrass (sourced from a seed cleaning plant by PGG Wrightson Seeds) sown in each replicate. The trial involved three replicates in a split plot design. Plots were 2 m wide and 9 m long. During 2019, the crop was regularly topped and not allowed to seed.

The trial was irrigated as required based on a soil moisture balance calculation. Fertiliser nitrogen (N) was applied as urea in autumn (70 kg N/ha on 25 May 2020) and spring (100 kg N/ha on 17 September

2020). Group 4 herbicide 2,4-D Ester was applied as a general broadleaf herbicide on 3 July. Clopyralid (Group 4) was applied on 15th November to control Californian thistles. The plant growth regulators Moddus® Evo (a.i. 250 g/L trinexapac ethyl) at 0.4 L/ha plus Cycocel® 2 L/ha (a.i. 750 g/L chlormequat chloride) were applied on 30 October and again on the 15 November.

Eleven herbicide treatments (mostly mixes or in a timing sequence) were evaluated with timings depending on herbicide type. Application dates and rates are shown in Table 2. The herbicides, their a.i. and MOA Group were; Nu-Trazine™ 900DF (a.i. 900 g/L atrazine, Group 5), Karmex® 800 DF (800 g/L diuron, Group 5), Goal™ (a.i. 480 g/kg oxyfluorfen, Group 14), Hussar®, Kerb™ , Alion® (a.i. 500 g/litre indaziflam, Group 29), Othello®OD (a.i. 50 g/L diflufenican + 2.5 g/L idosulfuron + 7.5 g/L mesosulfuron, Groups 2 & 12) Sencor® 600SC (a.i. 600 g/L metribuzin, Group 5), Sakura®850 WG (a.i. 850 g/kg pyroxasulfone, Group 15), Stratos™ (a.i. 200 g/L flamprop-M-isopropyl, Group 0) and Foxtrot® (a.i. 69 g/L fenoxaprop-p-ethyl, Group 1). Stratos™ and Foxtrot® were applied for wild oat control.

Visual evaluations of crop and grass weed damage were recorded on the 31 August 2020 using a scoring system of 0 = no damage, 100 = complete control. Seed head density was used as a surrogate for seed yield as these were single row plots. Seed head density was evaluated on 14 December by cutting 1 m of row and counting fully emerged seed heads.

Data were analysed using to analysis of variance (ANVOA) with means separation achieved via Fishers Least Significant Difference (LSD $\alpha = 0.05$) test if the overall P value was less than 0.05, using Genstat 19.

Results and Discussion

A 100 % control of perennial and annual ryegrass, and hairgrass was achieved in all treatments, with the exception of Hussar®, which had no activity on hairgrass (Table 2). A low level of phytotoxicity was visible (up to 12% on some cocksfoot cultivars), but no herbicide by cultivar interaction ($p=0.57$). For seed head density, there was also no interaction between cultivar and herbicide treatment ($p=0.96$), meaning all cultivars responded in a similar way to each herbicide treatment.

Seed head density was different between cultivars, ranging from 280 heads/m^2 for 'Kainui' up to 420 heads/m^2 in 'Howlong' (Table 1). Six herbicide treatments had similar head densities to the untreated control and five treatments, including the industry standard of atrazine plus diuron, reduced head densities by between 17 and 29% (Table 1).

The addition of Kerb™ and both the wild oat control herbicides (Stratos™ and Foxtrot®) in sequence, did not significantly reduce seed head numbers further than the atrazine plus diuron treatment. The addition of herbicides Alion® or Othello® to atrazine plus Karmex®, or replacing atrazine plus Karmex® with a mix of Sakura®, Goal™ and Sencor® did not significantly reduce cocksfoot seed head density (Table 2).

Summary

The susceptibility of 12 cocksfoot cultivars to a range of herbicides tested in this trial primarily for grass weed control in second-year crops was were not significantly different. The widely used herbicides Karmex® and Nu-Trazine™ 900DF (Group 5 herbicides) reduced cocksfoot seed head numbers in some, but not all treatments. This is in contrast to the previous year, where seed head density was increased significantly over the non-herbicide treated control (Rolston and Chynoweth, 2020). Kerb™, a Group 3 herbicide used commonly in cocksfoot in the United States, also showed potential as an additive to Group 5 triazine and urea herbicides for the control of weedy grasses in cocksfoot. Foxtrot® or Stratos™ (Groups 1 and 0, respectively) could also be used in conjunction with the primary herbicides if wild oat control was needed in spring. In 2021-22, a field trial in a grower's field will be undertaken to collect seed yield data to confirm cocksfoot tolerance in the row trials.

References

Rolston, P, Vreugdenhil, S, Chynoweth, R (2019). Herbicide tolerance of first year cocksfoot cultivars. *FAR Research Results 2018/19*: Pp. 88-91.

Rolston, P, Chynoweth, R (2020). Herbicide tolerance of second-year cocksfoot cultivars 2020. *SIRC Research Results 2019/20*: Pp. 25-27.

Table 1. Mean seed head density at mid-seed fill, 14 December 2020, for 12 cultivars of cocksfoot, when grown as second-year crops near Lincoln in the 2020-21 growing season.

Cultivar	**Heads/m^2***	
Howlong	420	c
Vision	370	bc
Aurus	370	bc
Safin	360	b
Refine	350	b
Savvy	350	b
SF Greenly II	350	b
Athos	340	b
Grasslands Kaha	340	ab
SF Oasis	340	ab
Kainui	280	a
Berta	280	a
LSD (p=0.05)	**62**	
P value	**<0.001**	

Note: Mean seed head numbers for cultivars was calculated as the mean from 11 independent herbicide treatments. Mean seed head numbers for cultivars highlighted yellow were among the highest statistically. *Mean seed head numbers with the same alphabetical letter are not significantly different.

Table 2. Mean weed control and crop tolerance in a second-year stand of cocksfoot grown at the FAR research site at Kowhai Farm, Lincoln in 2020-21, following treatment with one of eleven herbicide programmes used for control of forage perennial ryegrass, hairgrass and Italian ryegrass weeds.

Treatment No.	**Herbicide products, rates (L or kg*/ha) and dates of application**			**Weed control (%)****			**Crop tolerance measures**	
	20 May 2020	**3 July 2020**	**9 September 2020**	**Perennial ryegrass**	**Hairgrass**	**Italian ryegrass**	**Cocksfoot damage score**	**Cocksfoot seed heads (#/m^2)**
1	Nil			0	0	0	0	410
2	Hussar® (0.2)			100	17	100	0	380
3	Nu-Trazine™ (1.5) + Karmex® (1.5)			100	100	100	11	340
4	Hussar® (0.2) + Atrazine (1.5) + Karmex® (1.5)	Alion® (0.05)		100	100	100	7	380
5	Hussar® (0.2) + Atrazine (1.5) + Karmex® (1.5)	Kerb™ (0.85)		100	100	100	7	380
6	Atrazine (1.5) + Karmex® (1.5)	Kerb™ (0.85)		100	100	100	12	290
7	Sakura® (0.15) + Goal™ (0.6) +Sencor® (0.44)	Kerb™ (0.85)		100	100	100	6	380
8	Hussar® (0.2)	Hussar® (0.2)		100	0	100	7	370
9	Othello® (1.0) + Nu-Trazine™ (1.5) + Karmex® (1.5)	Kerb™ (0.85)		100	100	100	12	330
10	Hussar® (0.2) + Nu-Trazine™ (1.5) + Karmex® (1.5)	Kerb™ (0.85)	Stratos™ (4.0)	100	100	100	9	310
11	Hussar® (0.2) + Nu-Trazine™ (1.5) + Karmex® (1.5)	Kerb™ (0.85)	Foxtrot® (0.75)	100	100	100	11	320
			LSD ($p=0.05$)	**4**	**4**	**4**	**5**	**62**
			P value	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**<0.001**

Cells highlighted yellow provide the treatments with the greatest mean weed control or the greatest mean crop seed head numbers. Means were calculated from treatment of 12 different cultivars. *Herbicide application rates provided in kg/ha. **Weed control measured on 31 August 2020. The herbicides, active ingredients (a.i) and Mode-of-Action Groups were: Nu-Trazine™ 900DF (a.i. 900 g/L atrazine, Group 5), Karmex® 800 DF (a.i. 800 g/L diuron, Group 5), Goal™ (a.i. 480 g/kg oxyfluorfen, Group 14), Hussar® (a.i. 50 g/kg iodosulfuron-methyl-sodium, Group 2), Kerb™ (a.i. 500 g/L propryzamide, Group 3) , Alion® (a.i. 500 g/L indaziflam, Group 29), Othello®OD (a.i. 50 g/L diflufenican + 2.5 g/L idosulfuron + 7.5 g/L mesosulfuron, Groups & 12), Goal™ 480 (a.i. oxyfluorfen, Group 14); Sencor® 600SC (a.i. metribuzin, Group 5). Sakura®850 WG (a.i. 850 pyroxasulfone, Group 15), Stratos™ (a.i. 200 g/L flamprop-M-isopropyl, Group 0) and Foxtrot® (a.i. 69 g/L fenoxaprop-p-ethyl, Group 1).

Cocksfoot seed yield response to spring applied irrigation

Project code H19-12

Duration Year 3 of 3

Authors Owen Gibson, Richard Chynoweth and Phil Rolston (FAR)

Location FAR Arable Site Chertsey, Mid Canterbury

Funding Seed Industry Research Centre (SIRC)

Acknowledgements NZ Arable (trial operator), Vantage NZ (soil moisture monitoring)

Key points

- Cocksfoot seed yield (940-1020 kg/hectare (ha)) and margin-over-irrigation cost ($910-1300/ha) were maximised when drought stress was avoided.
- Early drought reduced seed head numbers and subsequently final seed yield.
- Irrigation can be reduced to 50% of the measured water use, as long as soil moisture status is monitored and stress point is avoided (approx. 50% of total water holding capacity).

Background

Water stress during spring and summer is common throughout the seed producing areas of New Zealand’s east coast where evapotranspiration commonly exceeds rainfall. If the stored soil water supply is insufficient, plant growth becomes limited, with symptoms such as wilting, leaf death, tiller death and crop dormancy. In grasses grown for seed, early spring drought generally reduces the number of tillers that produce seed heads, while late season drought reduces seed size and thus the number of saleable seeds harvested. This trial was set up to investigate the response of a cocksfoot seed crop to spring drought and quantify if early or late season drought is more detrimental.

Methods

The trial was set up in a fifth year stand of cultivar ‘Savvy’ cocksfoot that was established in February, 2016. Following harvest, the straw was removed and volunteer cocksfoot and ryegrass seedlings were controlled using a combination of Hussar® (active ingredient (a.i.) 50 g/kg iodosulfuron) applied 7 May and two applications of Atranex® WG (a.i. 900 g/kg atrazine) plus Karmex® DF (a.i. 800 g/kg diuron) applied 2 June and 3 July. Autumn nitrogen (N) application was 80 kg N/ha split between 40 kg N/ha applied as SustaiN® on 25 March and 40 kg N + 45 kg S applied as Ammonium Sulphate on 4 May. Spring N application consisted of one application of 40 kg N/ha + 16 kg S/ha as ammo™ 31 and of 80 kg N/ha applied as SustaiN® split between August and November. Two applications of 1.5 L/ha of Cycocel™ 750 (a.i. 750 g/L chlormequat-chloride) plus 0.4 L/ha of Moddus® Evo (a.i. 250 g/L trinexapac ethyl) were applied to all plots on 13 and 22 October. Two applications of 0.4 L/ha Proline® (a.i. 250 g/L prothioconazole), 0.6 L/ha Seguris® Flexi (a.i. 125 g/L isopyrazam) and 3 L/ha Tri-Base Blue® (a.i. 190 g/L copper as $CuSO_4$) were applied 22 October and 22 November.

The soil type was a Chertsey Silt Loam with ~55 cm of topsoil above free draining gravel. The water holding capacity is ~120 mm of which half is freely plant available. Irrigation was applied to the in-between row space of each plot via an above ground trickle tape system with drippers spaced approximately 33 cm apart. A single application was applied weekly based on measured soil moisture levels at an application rate of ~8 mm/hr. Soil moisture was measured in all plots at hourly intervals in the 0-20 cm layer using Campbell Scientific CS650 reflectometers. At weekly intervals, the day prior to irrigation application, soil moisture between 20 and 50 cm was measured by neutron probe to give the weekly measured soil water deficit. Rainfall was measured on site by the NIWA weather station.

On 31 December, a 0.125 m^2 quadrant was cut from each plot to assess total dry matter production and the number of seed heads produced. All plots were windrowed on 11 January 2021 using a modified John Deere windrower and were harvested on 18 January using a 'Sampo' plot combine. A sub-sample was machine-dressed to a First-Generation Seed Certification standard.

Margin-over-cost (MoC) was calculated with an irrigation cost of $2.50/mm applied water and cocksfoot seed grower price (net of seed cleaning costs) at $4.50/kg.

The trial design was a randomised complete block with four replicates, data was analysed by ANOVA and regression analysis using Genstat19.

Weather data

The soil moisture status was 'full' at the end of June following 80 mm of rainfall (Table 2). The accumulated soil moisture deficit increased during spring as evapotranspiration exceeded rainfall. ~90 mm of rainfall was recorded from flowering (early December) onward which removed the potential for late drought to develop in this experiment.

Table 2. Measured rainfall and calculated evapotranspiration from June until windrowing for the experimental location at the FAR Arable Research Site, Chertsey, Mid Canterbury in the 2020-21 season.

Month	Evapotranspiration (mm)	Rainfall (mm)	Potential accumulated deficit (mm)
June	20.7	80.2	-
July	28.3	36	0
August	45.8	16.6	29.2
September	85.5	37.2	77.5
October	105.8	19.2	164.1
November	121.1	76	209.2
December	142.1	67.8	283.5
January 1-11 2021	43.2	23	303.7
Total	**592**	**356**	

Results and Discussion

Seed yield was increased by all irrigation treatments compared with the untreated control (Table 3). The October-November drought (Treatment 2) reduced seed yield by ~200 kg/ha compared with the fully irrigated treatments (Table 3). With no late season drought, so treatments imposed post-flowering were no different from replacing the measured water use (MWU), i.e. treatments 4-6.

Seed yield was not reduced when 50% of the MWU was replaced weekly as the soil moisture reserves were maintained above stress point when replacing 50% of MWU. This scheduling method allows the soil to capture and store rainfall as it occurs during the season with reduced drainage compared with the fully irrigated plots. However, in dry seasons, if the soil moisture deficit becomes large, this method can lead to drought stress and yield reductions.

Seed yield increases were primarily due to increases in seed head density and crop biomass (Table 4) until ~140 mm of applied irrigation, there was no difference in thousand seed weight between treatments (data not shown).

Irrigation had a positive effect on MoC, returning between $600 in Treatment 2 (mid-drought followed by replace MWU) to $1380 in Treatment 4 (Replace MWU until early seed fill) (Table 3).

Table 3. Seed yield of cocksfoot, cultivar Savvy, following the application of seven irrigation treatments based on replacing measured water use (MWU) when grown on a Chertsey silt loam soil type with a readily available water content of ~60 mm, grown near Chertsey, Mid Canterbury in the 2020-21 season.

	Treatment	Applied water (mm)	Maximum measured deficit (mm)	Seed yield (kg/ha)		MoC[1] ($/ha)	
1	No irrigation	-	104	580	d	0	c
2	Mid drought f.b.[2] MWU	155	77	740	c	600	bc
3	Replace MWU until flowering	125	99	840	bc	910	ab
4	Replace MWU until early seed fill	210	73	940	ab	1380	a
5	Replace MWU until mid-seed fill	250	71	910	ab	1110	ab
6	Replace MWU	280	66	1020	a	1300	a
7	50% of MWU	140	71	910	ab	1190	a
			P value	**<0.001**		**0.009**	
			LSD (p=0.05)	**136**		**630**	

Note: Yellow indicates the treatments that produced the greatest seed yield or largest Margin-over-cost (MoC). [1]MoC, relative to the control. [2]f.b. = followed by.

Table 4. Harvest components of cocksfoot, cultivar 'Savvy', following the application of seven irrigation treatments based on replacing measured water use (MWU) when grown near Chertsey, Mid Canterbury in the 2020/21 growing season.

	Treatment	Applied water (mm)	Dry matter (kg/ha)	Heads/m^2
1	No irrigation	-	6890	322
2	Mid drought f.b.[1] MWU	155	10070	475
3	Replace MWU until anthesis	125	11400	485
4	Replace MWU until early seed fill	210	14250	553
5	Replace MWU until mid-seed fill	250	13650	530
6	Replace MWU	280	15900	499
7	50% of MWU	140	13550	573
		P value	**0.028**	**0.05**
		LSD (p=0.05)	**5059**	**151**

Note: Yellow indicates the treatments that produced the greatest dry matter or largest number of heads/m^2.
[1]f.b. = followed by.

Summary

Adequate soil water supply is essential to maximise seed yield in cocksfoot. During spring, the crop requires water to produce sufficient seed head numbers to maximise the potential yield. Weekly irrigation rates can be reduced to replacing 50% of measured water use where soil moisture status is monitored and maintained above stress point (~70 mm at this site).

References

Chynoweth, R and Rolston, P (2020). Cocksfoot seed yield response to irrigation. *SIRC Research Results 2019/20*. Pg. 28-30.

Cocksfoot seed yield response to spring nitrogen

Project code	H19-15
Duration	Year 4 of 4
Authors	Owen Gibson, Phil Rolston, FAR
Location	Barenbrug, Courtenay (Old West Coast Road) -43.452714, 172.182106
Funding	Seed Industry Research Centre (SIRC)
Acknowledgements	Barenbrug Courtney Research Station (trial hosts); NZ Arable (trial operators)

Key points

- A total nitrogen (soil mineral N + applied N) of 125 kg/ hectare resulted in the greatest cocksfoot seed yield using the least amount of applied nitrogen. The margin-over-nitrogen cost (MoC) for this treatment was $916/ha.
- Seed yield and MoC for crops with access to more than 125 kg/ha total N were not statistically different, except seed yield decreased by 14% when total N was 225 Kg/ha.
- Seed yield was increased by an increase in seed head number.
- The nitrogen nutrition index (NNI) calculated treatment was comparable in yield to treatments receiving higher amounts of nitrogen and equivalent N at different timings.

Background

This trial is part of a series to define the spring nitrogen (N) requirements for cocksfoot seed crops. Cocksfoot tillers that become reproductive are formed in autumn and winter. Spring N is used to ensure reproductive tillers are not nutrient limited during their development. The previous trials undertaken between 2016 and 2019 indicated that with typical grower autumn-winter management, the spring N requirement for cocksfoot is less than perennial ryegrass with optimum spring N being 129 ±10 kg N/ha.

Nitrogen Nutrition Index (NNI) is used to guide N decision making in some crops. The NNI is based on the dilution curve of increasing biomass against declining foliar N% (Gislum & Boelt 2009). When the NNI is below the critical N (usually 1.0), the crop will respond to additional N. The trial reported here adds to datasets on N responses in cocksfoot and provides more species-specific data for improving the Overseer model and its reliance on 'proxy' crops.

Method

The trial was setup in an irrigated paddock of second year cocksfoot, cultivar DG30 located at Barenbrug in Courtenay, Canterbury. Trial management was as per the trial host's management of the paddock, except for nitrogen fertiliser applications (Appendix 1). Soil mineral N (NO_3 + NH_4) (0-30 and 30-60 cm) was assessed on 13 August 2020 at the time of trial set-up and was 25 kg N/ha. The trial evaluated nine nitrogen (N) treatments where total N (mineral N + applied N) input ranged from 25 to 250 kg N/ha, with fertiliser applied as SustaiN® (46% N) (Table 1). Treatment 9 used the Nitrogen Nutrition Index (NNI) developed for ryegrass (Gislum and Boelt 2009) to estimate the final N required based on the plant herbage N% and the biomass. These were 2.45% N and 4690 kg DM/ha, respectively on 14th October, when treatments were assessed. An average NNI value of 0.81, gave an estimated 46 kg N/ha to achieve a critical N of 1.0. Treatments were replicated four times in a randomised block design. Plots were 3.3 m wide and 10 m long. Crop dry matter and head density was assessed on 15 January 2021 by cutting a 0.3 m^2 quadrat (1 row x 1 m), and oven drying a subsample at 70°C for 48 hours.

The trial was windrowed on 18 January, cutting a 1.8 m swath from the centre of each plot and harvested on 26 January with a plot combine. The seed was dressed to a First-Generation seed certification standard and machine-dressed (MD) seed yield calculated. The margin-over-cost (MoC) analysis used a cocksfoot grower price of $4.50/kg, SustaiN® at $1.95/kg N, and application costs at $20/ha/application. Statistical analysis used GenStat v19.

Results and Discussion

Seed yield increased from 520 kg/ha in the untreated control to 835 kg/ha when a total N of 175 kg/ha (150 kg N/ha applied) was available to the crop, a 58% increase in yield (Table 1). However, with the exception of the crop treated with 250 kg total N/ha (which reduced seed yield), seed yields for crops with access to 125 kg/ha total N or more were not statistically different.

The use of the NNI calculator to predict nitrogen application resulted in a similar seed yield to the corresponding treatment (Treatment 4) in which total N supply was similar but N application timings were different. This result indicated that the window for spring N application can extend until at least late October.

Head numbers in the trial increased with applied nitrogen (Figure 2), but this did not lead to increased seed yield above 150 kg total N (Figure 1) where ~800 head/m2 were produced. Significant lodging did not occur with increasing N rates (data not shown). The yield reduction when 175 kg/ha or greater nitrogen was applied in the spring resulted in no visible lodging, which is usually the cause of yield reductions in grass seed crops.

The greatest MoC ($1045) was also achieved using a total N of 175 kg/ha, but again this was also statistically similar to all other treatments receiving N fertiliser.

Summary

The optimal quantity of spring N to maximize yield and returns in this trial was 125 kg N/ha (100 kg N/ha applied + 25 kg N/ha soil), similar to the quantity identified in the previous nitrogen trials in cocksfoot. This was closely mirrored by the NNI calculated (Treatment 9) treatment with 120 kg N/ha total nitrogen. This provides confidence in the NNI calculator as a means of making nitrogen decisions during the spring period when nitrogen fertiliser is applied. Seed yield was increased by an increase in seed head number.

Table 1. Machine-dressed seed yield and margin-over-cost for cocksfoot, cultivar DG30, when grown near Courtenay, Canterbury in the 2020-21 growing season following the application of one of nine spring nitrogen (N) treatments.

Treatment	Date and rate of applied N (kg/ha)				Total applied N (kg/ha)	Total N (kg/ha)	Seed yield (kg/ha)	MoC[2] ($/ha)
	21 Aug	9 Sep	25 Sep	25 Oct				
1	0	0	0		0	25	520	0
2	0	25	0		25	50	670	605
3	20	30	25		75	100	700	617
4	20	55	25		100	125	780	916
5	30	65	30		125	150	780	877
6	30	65	55		150	175	835	1047
7	40	70	65		175	200	770	737
8	60	80	85		225	250	720	657
9[1]	20	0	28	47	95	120	740	744
						LSD (p=0.05)	**114**	**NS**
						P value	**<0.001**	**0.469**

Note: Yellow indicates the treatments that produced the greatest seed yield and largest margin-over-nitrogen cost (MoC). [1] NNI = treatment, [2] MoC = margin-over-nitrogen cost where cocksfoot seed price = $4.50/kg; SustaiN = $1.95/kg N, application costs = $20/ha/application.

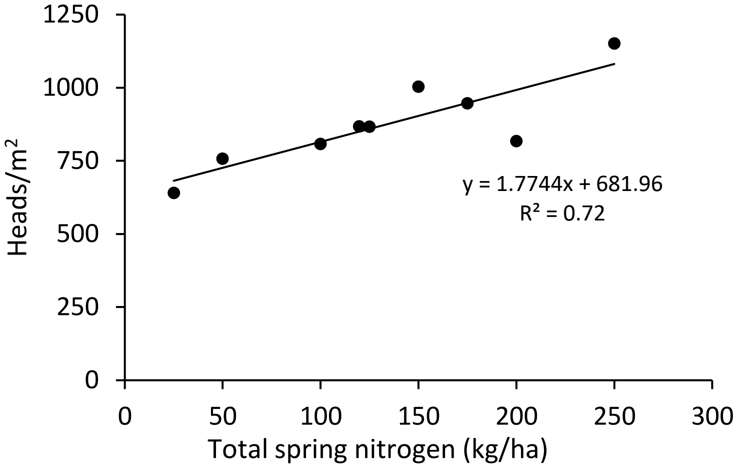

Figure 1. Head numbers of cocksfoot, cultivar DG30, following treatment with nine rates of nitrogen when grown near Courtney, Canterbury in the 2020-21 growing season. Total N is the sum of applied plus soil mineral N.

Reference

Gislum, R and Boelt, B (2009). Validity of accessible critical nitrogen dilution curves in perennial ryegrass for seed production. *Field Crops Research* 111: 152-156.

Appendix 1
Trial inputs

Cultivar: DG30
Sowing Date: 12th March, 2019
Nitrogen: As per the treatment list (table 1)
Herbicide: 1st April, 2020 - Karmex® (900 g/kg Diuron, Group 5) 1.7 kg/ha + Atranex® (Atrazine, Group 5) 0.7 L/ha
26th May, 2020 – Nortron® 500 g/L (Ethofumesate, Group 15) 2 L/ha
PGR: 1st October, 2020 – Moddus (250 g/L trinexapac-ethyl) 500 mL/ha + Cycocel® (750 g/L Chlormequat chloride) 1 L/ha
13th October, 2020 – Moddus® (250 g/L trinexapac-ethyl) 500 mL/ha + Cycocel (750 g/L Chlormequat chloride) 1 L/ha
Fungicide: 1st October, 2020 – Penncozeb® (750 g/kg Mancozeb, Group M3) 1.5 kg/ha + Tribase Blue® (190g/L Copper, Group M1) 2 L/ha
13th October, 2020 – Seguris flexi® (125 g/L isopyrazam, Group 7) 0.4 L/ha
2nd December, 2020 – Prosaro® (125 g/L prothioconazole and 125 g/L tebuconazole, Group 3) 0.5 L/ha + Amistar® (250 g/L Azoxystrobin, Group 11) 0.5 L/ha
8th January, 2021 – Proline® (250 g/L prothioconazole, Group 3) 0.35 L/ha + Seguris Flexi® (125 g/L isopyrazam, Group 7) 0.6 L/ha + Cusol® (92.8 g/L copper, Group M1) 1.5 L/ha + Vanir (49 g/L Nitrogen (N), 70 g/L Calcium (Ca), 87 g/L Magnesium (Mg), 84 g/L Manganese (Mn), 47 g/L Boron (B), 4 g/L Molybdenum (Mo) and 74 g/L Sulphur (S), with added Humic Acid - 1 L/ha)
Irrigation: 6th October 2020 – 40 mm
25th October 2020 – 50 mm
9th December 2020 – 30 mm
18th December 2020 – 30 mm Total: 150 mm in 4 irrigation events

Control of Phomopsis stalk disease on two plantain cultivars grown for seed

Project Code H19-16

Author Owen Gibson, Phil Rolston and Richard Chynoweth (FAR)

Duration Year 3 of 5

Location FAR Kowhai Research Site, Lincoln (GPS: 43° 28’ 24” S; 172° 28’ 14” E)

Funding Seed Industry Research Centre (SIRC)

Acknowledgements NZ Arable (trial operator)

Key points

- If left untreated, the incidence of Phomopsis stalk disease was 79 to 84% in two second-year plantain crops compared with 6 to 24% in a first-year crop the previous year.
- Seed yield was increased by all fungicide treatments, but production of a second-year crop remained uneconomic.
- Seed yields from the two second-year crops treated with the best performing fungicide programmes were up to 64% lower than the seed yields from the best performing treatments in the trial using a first-year plantain crop the previous year.
- Fungicide programmes that included a mixture of two fungicide groups produced seed yields that were higher than when Proline® (a.i. 250 g/L prothioconazole, Group 3) was used alone.

Background

Phomopsis stalk disease, caused by *Phomopsis subordinaria* (Figure 1), results in the collapse of stems below the seed head of plantain (*Plantago lanceolate*) and seed heads that produce no seed. Disease control by growers typically relies on the Group 3 demethylation inhibitor (DMI) active ingredient (a.i.) prothioconazole (e.g. Proline®). This project was developed to understand the impact of Phomopsis stalk disease on seed yield of plantain and to develop additional management options. Two cultivars, Agritonic and Boston, were compared where AgriTonic flowers four weeks earlier than Boston. In 2019-20, seed yields were increased by an average of 24% (480 kg extra seed/ha) by four different treatments with Proline® used either alone or in mixture. No yield differences were observed between these four treatments (Gibson *et al.* 2020). The 2020-21 trial repeated the previous years’ trial using the crop as a second-year plantain seed crop (utilising the same plots as the previous season).

Figure 1. Phomopsis stalk disease in plantain. The seed head on the left is at an early infection stage whereas the seed head on the right is collapsing with Phomopsis stalk disease.

Methods

An irrigated trial was established at FAR Kowhai Research Site to evaluate the effect of five fungicide treatments on the production of two plantain cultivars, AgriTonic (PGG Wrightson) and Boston (SeedForce/Norwest Seed) (Table 1). Treatments were in a randomised complete block design with three replicates. The trial was on a Wakanui silt loam. Crop management details are shown in Appendix 1.

All fungicide applications were made with a battery operated 2.8 m hand held plot boom with 6, 110 015xr AI tee jet nozzles at a working pressure of 250 kpa delivering 165 L/ha water at a walk speed of 3.6 kph. The fungicides evaluated were Amistar® (a.i. 250 g/L azoxystrobin, Group 11), Proline® (a.i. 250 g/L prothioconazole, Group 3), Prosaro® (a.i. 125 g/L prothioconazole and 125 g/L tebuconazole, Group 3), and Seguris® flexi (a.i. 125 g/L isopyrazam, Group 7) applied twice either alone or in mixtures at mid-flowering (20 November (cv. AgriTonic) and 8 December (cv. Boston)) and repeated 14 days later (Table 1). Disease assessments were made by sampling 50 heads per plot at harvest, and separating into those with diseased, non-diseased and immature heads. The data presented on percent diseased heads excluded the immature heads.

The field-dressed seed was cleaned with a screen-air seed cleaner. Results were analysed using Genstat®19th Edition (VSN 2019).

Margin-over-cost (MoC) relative to the untreated control yield was calculated for each treatment, based on a grower's price of $4.00/kg for seed, the fungicide costs and $20/ha per application cost.

Results and Discussion

Average seed yield of 660 kg/ha for cv. AgriTonic was larger than the 540 kg/ha for cv. Boston (Table 1). In 2019-20, the seed yields of both plantain cultivars were similar at 2,300 kg/ha for cv. AgriTonic and 2,410 kg/ha for cv. Boston as first-year crops.

There was no fungicide by cultivar interaction, suggesting both cultivars responded to fungicide treatment in the same way. Seed yield was increased by all fungicide treatments (Table 1), however those containing two product groups were higher than Proline® alone (Table 1).

For the percentage of stems infected with *Phomopsis* stalk disease, there was a cultivar by fungicide interaction where the later heading cv. Boston had less *Phomopsis* stalk disease following fungicide treatment, although both cultivars had high infection levels (79-84%) in the untreated plots (Table 2). Fungicides reduced the incidence of neck-break from 31 to 10% of heads in cv. Boston and 58 to 32% in cv. AgriTonic (data not presented).

Commercially, seed growers do not attempt to grow second-year plantain seed crops. While fungicides significantly reduced the incidence of *Phomopsis* stalk disease, the levels of infection were still higher than the levels seen in the first-year untreated plots (Gibson *et al.* 2020).

There was a large economic response to fungicide treatment with the highest average MoC relative to the untreated control in both cultivars being, Prosaro® plus Amistar® ($2,890/ha) and Proline® plus Amistar® ($2,620/ha). Treatments with Proline® ($1,810/ha) and Proline® + Seguris® Flexi ($2060/ha) resulted in lower returns ($LSD_{0.05}$ = $540/ha).

Summary

Fungicide treatment reduced stalk disease and increased seed yields in second-year plantain crops. However, stalk disease remained sufficiently yield-limiting even with fungicide treatment to make second-year crops a non-viable commercial option.

Table 1. Seed yield of second-year plantain following treatment with five fungicide programmes on two cultivars when grown near Lincoln, Canterbury in the 2020-21 season.

	Fungicide treatment (L/ha) applied mid-flowering + 14 days [1]	**Seed yield (kg/ha)**		**Fungicide mean (kg/ha)**
		cv. AgriTonic	**cv. Boston**	
1	nil	120	90	105 c
2	Proline® (0.8)	630	540	585 b
3	Proline® (0.8) + Seguris® Flexi (0.6)	750	570	660 ab
4	Proline® (0.8) + Amistar® (0.5)	790	800	795 a
5	Prosaro® (1.0) + Amistar® (0.5)	1000	720	860 a
	Cultivar mean	**660 a**	**540 b**	
			LSD (p=0.05)	**204**
			P value – fungicide trt[2]	**<0.01**

Note: Yellow indicates the treatments with the greatest mean seed yields. [1]cv. AgriTonic application dates were 20 November and 8 December, 2020, while cv. Boston application dates were 8 December and 22 December, 2020. [2]P value interaction = 0.238, P Value cultivar =0.017.

Table 2. Average percentage of heads infected of second-year plantain with *Phomopsis* stalk disease following the application of five fungicide treatments on two cultivars grown at Lincoln, Canterbury in the 2020-2021 growing season.

Treatment number	**Fungicide treatment and dose (L/ha) (Mid-Flowering + 14 after Application[1])**	**diseased heads (%)**	
		cv. AgriTonic	**cv. Boston**
1	nil	84	79
2	Prosaro® (1.0) + Amistar® (0.5)	36	21
3	Proline® (0.8)	58	22
4	Proline® (0.8) + Seguris Flexi® (0.6)	41	31
5	Proline® (0.8) + Amistar® (0.5)	32	19
	LSD (p=0.05)	**17**	
	P value, cultivar * fungicide	**<0.001**	

[1]'AgriTonic' application dates – 20 November 2020 + 8 December 2020, 'Boston' application dates – 8 December 2020 + 22 December 2020

Reference

Gibson, O, Rolston, P, and Chynoweth, R (2020). Control of Phomopsis stalk disease on two plantain cultivars grown for seed. *SIRC Research Results 2019/2020*: Pp. 42-44.

Appendix 1. Trial management information.

Sowing date:	25 March 2019
First-year harvest:	18 January 2020 (AgriTonic) and 18 February 2020 (Boston).
Post-harvest management:	Straw removed. Autumn N 30 kg N/ha applied 5 May 2020.
Soil mineral N:	Soil mineral N (NO_3 and NH_4) was assessed (Hill Laboratories) on 20 May 2020. At 0-30 cm N = 26 kg/ha and at 30-60 cm, 14 kg/ha. Thus, total soil N = 40 kg N/ha.
Spring N:	N applied as SustaiN® (46% N) on 21 August 2020; 6 October and 22 October with rates shown in Table 1.
Weed control:	Kamba®750 (a.i. 750 g/L dicamba, Group 4) 0.6 L/ha for general broadleaf weed control on 30 July 2020; Gallant™ Ultra (a.i. 520 g/L haloxyfop, Group 1) 120 mL/ha + Uptake Oil (26 August 2020); Gromoxone®250 (a.i. 250 g/L Paraquat, Group 22) 2 L/ha applied 21 September 2020.
Insecticide:	Lorsban® 50 EC (a.i. 500 g/L chlorpyrifos, Group 1) 1 L/ha applied on 4 November, 30 November and 22 December 2020.
Fungicide:	Proline® (a.i. 250 g/L prothioconazole, Group 3) 0.4 L/ha + Seguris® flexi (a.i. 125 g/L isopyrazam, Group 7) 0.6 L/ha applied 20 November and 8 December 2020.
Windrowing:	AgriTonic plots on 11 January, 2021, and the cv. Boston plots on 4 February, 2021, with a modified 1.8 m John Deere windrower.
Harvest:	AgriTonic plots 25 January, 2021, and cv. Boston plots on 15 February, 2021 with a Wintersteiger Elite Nursery master combine. The field dressed seed was cleaned with a screen-air seed cleaner.

Plantain grown for seed: response to spring nitrogen

Project Code H19-16

Author Phil Rolston, Owen Gibson and Richard Chynoweth (FAR)

Duration Year 1 of 2

Location FAR Kowhai Research Site, Lincoln (GPS: 43° 28’ 24” S; 172° 28’ 14” E)

Funding Seed Industry Research Centre (SIRC)

Acknowledgements NZ Arable (trial operator)

Key points

- The seed yield of a second-year plantain crop was only one third of the yield achieved by a first-year crop in the previous year.
- The total spring Nitrogen (N) (soil mineral + applied N) that produced the greatest yield and minimised the cost of N inputs was 139 kg N/ha. Additional N produced similar yields, but increased N input costs.
- Increasing spring N supply increased crop biomass and seed head number, but did not cause significant lodging.

Background

The nitrogen (N) responses of plantain seed crops have not previously been reported. This study was undertaken to understand the N response of a second-year plantain seed crop and to assist in providing data that might be used to refine the Overseer Model that currently uses ryegrass as a proxy crop for many small seed crops, including plantain.

Methods

The trial was in a second-year plantain crop sown with cv AgriTonic, previously used to evaluate herbicide tolerance. The trial was on a Wakanui silt loam. Eight N treatments were evaluated in a randomized block trial with four replicates. Soil mineral N was measured 20 May 2020 at 40 kg N/ha (0-60 cm). The trial area was irrigated, with decisions based on rainfall and evapotranspiration rates. Crop management details are shown in Appendix 1. Crop biomass and seed head density was assessed on the 10 December (mid-seed fill) by cutting 0.25 m^2 quadrates in each plot. Biomass N% (Hill Laboratories) was assessed on all plots and N uptake calculated. Lodging was assessed weekly from the 10 December to 10 January. Results were analysed using Genstat®19th Edition (VSN 2019).

Table 1. Spring nitrogen (N) treatments as SustaiN® and application dates for a second-year plantain crop grown in Lincoln in the 2020-2021 season.

Treatment	Nitrogen* application rates (kg/ha) and dates			Spring Applied N (kg/ha)	Total N (Soil + Applied) (kg/ha)
	21.8.20	6.10.20	22.10.20		
1	0	0	0	0	40
2	30	0	0	30	70
3	30	20	20	70	110
4	30	40	40	110	150
5	30	60	60	150	190
6	30	80	80	190	230
7	30	100	100	230	270
8	30	120	120	270	310

*N fertiliser applied as SustaiN®

Results and Discussion

Seed yield was increased by up to 172% above the untreated control by the highest yielding treatments. These treatments had total N of 110 kg/ha or more. Lodging averaged 10 to 15% at the highest N rates, but did not contribute to yield loss. Crop biomass yield, N% and seed head density increased with N application (Table 2), but seed yield plateaued at total N of 139 kg N/ha (Figure 1). Nitrogen uptake by the plant was positively related with an increase in N applied (Table 2; Figure 2).

Commercially, seed growers do not attempt to grow second-year plantain seed crops, partly because of the impact of Phomopsis stalk disease. While the fungicides used significantly reduced the incidence of this disease, the levels of infection were still far higher than in the first-year untreated plots and the seed yields were about one-third of the seed yield produced by the first-year crop on the same site.

Table 2. Total nitrogen (N) [Soil (0-60 cm) + Applied N], herbage mass at mid-seed fill, seed head density, N-uptake at mid-seed fill and seed yield for second-year plantain at Lincoln in 2020-21.

Treatment	Total N (kg N/ha)	Biomass (DM kg/ha)	Biomass N (%)	Seed heads (m^2)	N uptake^1 (kg N/ha)	Seed Yield (kg/ha)	
1	40	2780	1.7	368	50	283	a
2	70	3420	1.7	538	58	318	ab
3	110	3870	1.7	515	74	483	bc
4	150	5190	1.9	723	105	649	c
5	190	5430	2.1	607	113	563	c
6	230	6340	1.9	787	121	532	c
7	270	6420	2.4	935	157	526	c
8	310	8470	2.4	1127	203	511	bc
	LSD$_{0.05}$	**1520**	**0.3**	**300**	**38**	**195**	
	P value	**0.037**	**<0.001**	**0.001**	**<0.001**	**0.013**	

[1] N uptake is calculated from the nitrogen content of dry matter (DM kg/ha).

Note Yellow indicates the treatments that produced the greatest seed yield. Yields with the same letter are not significantly different.

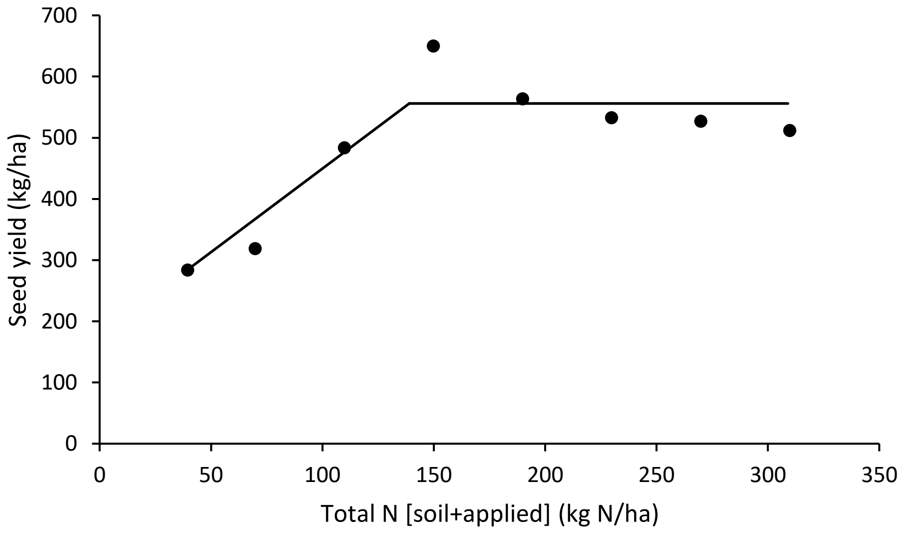

Figure 1. Seed yield of second-year plantain following treatment with eight nitrogen rates described using a split-line regression when grown at Lincoln in the 2020-21 season.

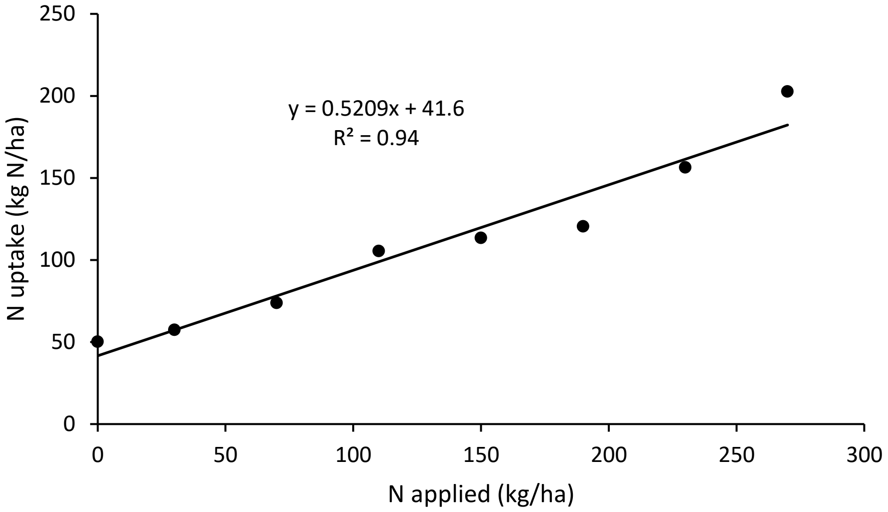

Figure 2. Nitrogen (N) uptake at mid-seed fill for a second-year plantain crop grown at Lincoln in the 2020-21 growing season when treated with eight spring nitrogen rates.

Summary

In a second-year plantain seed crop cv. AgriTonic, the total spring N (soil mineral N 0-60 cm + applied N) that provided the greatest increase in yield and minimised input costs was 139 kg N/ha. Nitrogen increased crop dry matter and seed head number but did not cause significant lodging.

Stalk disease caused by *Phomopsis* was not fully controlled in this crop and was a limiting factor in seed yields, which were 66% lower than we obtained in the first-year plantain seed crop at the same site the previous year, despite the use of a fungicide programme.

Appendix 1. Trial management information.

Sowing date:	25 March 2019
First-year harvest:	18 January 2020 (cv. AgriTonic)
Post-harvest management:	Straw removed. Autumn N 30 kg N/ha applied 5 May 2020.
Soil mineral N:	Soil mineral N (NO_3 and NH_4) was assessed (Hill Laboratories) on 20 May 2020. At 0-30 cm N = 26 kg/ha and at 30-60 cm, 14 kg/ha. Thus, total soil N = 40 kg N/ha.
Spring N:	N applied as SustaiN® (46% N) on 21 August 2020; 6 October and 22 October with rates shown in Table 1.
Weed control:	Kamba®750 (a.i. 750 g/L dicamba, Group 4) 0.6 L/ha for general broadleaf weed control on 30 July 2020; Gallant™ Ultra (a.i. 520 g/L haloxyfop, Group 1) 120 mL/ha + Uptake Oil (26 August 2020); Gromoxone®250 (a.i. 250 g/L Paraquat, Group 22) 2 L/ha applied 21 September 2020.
Insecticide:	Lorsban® 50 EC (a.i. 500 g/L chlorpyrifos, Group 1) 1 L/ha applied on 4 November, 30 November and 22 December 2020.
Fungicide:	Proline® (a.i. 250 g/L prothioconazole, Group 3) 0.4 L/ha + Seguris® flexi (a.i. 125 g/L isopyrazam, Group 7) 0.6 L/ha applied 20 November and 8 December 2020.
Windrowing:	11 January, 2021with a modified 1.8 m John Deere windrower.
Harvest:	25 January, 2021, with a Wintersteiger Elite Nursery master combine. The field dressed seed was cleaned with a screen-air seed cleaner.

Sow thistle control options in white clover

Project code H19-18

Authors Owen Gibson, Phil Rolston, Richard Chynoweth (FAR)

Duration Year 3 of 3

Location Barrhill, Mid-Canterbury (-43.634700, 171.802813)

Funding Seed Industry Research Centre (SIRC)

Acknowledgements Ian Maw (trial host), NZ Arable (trial operator)

Key Points

- Early (July) treatment of a first-year white clover crop with an herbicide programme containing diflufenican (Groups 12), bromoxynil (Group 6) and 2, 4-D Ester (as the ethylhexyl ester, Group 4) provided good sow thistle control, did not require a spring follow-up herbicide and provided a positive return-on investment.
- When applied early (July) as a stand-alone herbicide treatment, herbicides containing MCPA reduced seed yield when compared to all other treatments and reduced margin-over-costs.
- However, if applying an early herbicide containing MCPA a follow-up spring herbicide treatment resulted in no difference in seed yield.
- The addition of Sharpen® to Tropotox® in July resulted in excellent sow thistle control.

Background

In white clover seed crops, sow thistles (*Sonchus* spp.) can be difficult weeds to control. Three subspecies, *Sonchus arvensis* (perennial sow thistle), *Sonchus asper* (spiny leaved sow thistle) and *Sonchus olerceus* (annual sow thistle) can be present at the same time. Generally, spiny and annual sow thistle are more problematic in Canterbury farming systems than perennial sow thistle. For the past ten years, the application of Jaguar® (active ingredient (a.i.) 25 g/L diflufenican and 250 g/L bromoxynil, Groups 12 and 6) and 2, 4-D Ester (e.g. Relay® Super S a.i. 680 g/L 2,4-D as the ethylhexyl ester, Group 4) during late winter has been the most commonly used control strategy for sow thistle. Alternative control options are late autumn application of herbicides to ‘hold’ the sow thistle and slow growth before these late winter applications. However, bare ground and aggressive growth regulation of clover can allow spring germination of thistles which can be damaging to clover seed yield where clover was late established or growth was reduced by pest pressure.

As Jaguar® has been removed from the market, new generic formulations of bromoxynil and diflufenican have been proven in previous trials to have the similar efficacy on sow thistle (Gibson and Chynoweth 2020). There is still uncertainty around the long-term availability of bromoxonil, therefore the need to research alternative herbicide options in the absence of bromoxynil products. Sharpen® (saflufenacil, Group 14) has shown positive results in white clover for sow thistle control, but can cause severe growth suppression when applied at label rate during winter dormant stage. The application of low rates of Sharpen® during winter application timings have shown we can get good early control of sow thistle without limiting the clover growth. The ability to apply MCPA (Group 4) early by itself or in herbicide mixture could benefit white clover seed crops by reducing sow thistle populations prior to spring growth. This trial evaluated both rates and timings for application of Sharpen® and MCPA.

Methods

The trial was established in an irrigated paddock of first-year white clover, cultivar Quartz, near Barrhill, Mid Canterbury. The paddock was sown on 28 February 2020 at 2.5 kg/ha with 7 kg/ha SuSCon® Green (a.i. 100 g/kg chlorpyrifos, Group 1). On 16 March, 50 kg/ha Cropmaster 15 (N - 15.1%, P 10%, K 10%, S 7.7%) was applied to the paddock with 5 kg/ha Endure® (a.i. metaldehyde 50 g/kg, Group 2B) slug bait.

The trial was a randomised complete block design with four replicates and 12 treatments. Plot size was 11.5 x 2.5 m. Herbicide rates and dates of application for the 12 treatments evaluated are shown in Table 1.

Visual assessments of clover damage, general weed cover, and thistle damage were carried out weekly from 3 August to 14 September, 2020. Scores were on a 0-10 scale, where 0 was no damage and 10 was dead. A pre-harvest dry matter cut (0.3 m2) from every plot was carried out on 17 February 2021, to determine total flower number and white clover biomass kg/ha. The trial was desiccated on 18 February 2020, with 3 L/ha Reglone® (a.i. 200 g/L diquat, Group 22) + 300 mL/ha Actiwett® (linear alcohol ethoxylate 935 g/L) and harvested on 23 February 2021, with a Wintersteiger plot combine harvester.

Statistical analysis was by general analysis of variance (ANOVA), using Genstat® 19th edition (VSN International Ltd, UK).

Results and Discussion

The field where the trial was located suffered greatly from sprouted seed and resulted in yields 50% lower than anticipated by the host farmer. The spiny leaved sow thistle was the predominant thistle in the trial area in August with an average of 120 plants/m^2. Annual sow thistle was also present at a lower population density of 18 plants/m^2 (data not shown).

The highest yield of clover seed was 474 kg/ha, achieved by treatments with Paraquat (2 L/ha) in July followed by MCPA (2 L/ha Agritone®) plus Sharpen® (25 g/ha) in September (Treatment 10). However, this was not significantly different to the untreated (that yielded 406 kg/ha) or a number of other treatments. Due to the weeds in the untreated control only resulting in a moderate depression in yield, the margin-over-chemical-costs (MoCs) were relatively low. The cost of applying herbicide did not significantly alter the MoC compared to the untreated (Table 1).

Early application of MCPA (July timing) had a detrimental effect on yield with all of the lowest yielding treatments receiving MCPA as a solo or in a mix during the July period (Treatments 4 to 7). The exception to this was Treatment 8 which still yielded 428 kg/ha when 1.0 L/ha MCPA was applied in July and a follow-up application of another 1.0 L/ha MCPA in August. Tropotox® Plus, containing a mix of MCPA and MCPB, combined with Sharpen® (5 g/ha) also had excellent sow thistle control, well above all other treatments, but required a second application in spring to ensure yield was maintained. These findings suggest that reduced white clover growth allows spring germination of sow thistle or other weeds to occupy bare ground that would otherwise be covered, necessitating a follow-up herbicide treatment in spring.

There was no significant difference between flower number or dry matter when the pre-harvest cuts were taken (data not shown).

Summary

In 2019-20, alternative herbicides to Jaguar® demonstrated good sow thistle control, while the addition of 2,4-D ester (Relay® Super S) to diflufenican + bromoxynil combinations also provided effective control and high seed yield. In 2020-21, MCPA herbicides Agritone® and Tropotox® Plus reduced clover growth when applied in July, ultimately reducing white clover seed yield. However, late applications of Agritone®, in combination with an earlier herbicide application did not reduce yield. Thus, a number of alternatives to Jaguar® are effective in controlling sow thistle.

Reference

Gibson, O, and Chynoweth, R (2020). Sow thistle control options in white clover. *SIRC Research Results 2019/2020*: Pp 48-52.

Table 1. Seed yield, thistle suppression and Margin-over-Cost for a first-year crop of white clover cultivar Quartz, grown near Barrhill, Mid-Canterbury in the 2010-21 growing season using different herbicide treatments for sow thistle control.

Treatment Number	Herbicide treatment, rate/ha and timing			Sow thistles[1] Control (Score: 1-10)	Seed yield (kg/ha)		MoC[2] ($/ha)	
	24 July 2020	26 August 2020	18 September 2020					
1	-	-	-	2	**406**	abc	0	bc
2	Argosy® (1.5 L) + Relay® (1.75 L)	-	-	7	**455**	c	174	bc
3	Argosy® (1.5 L) + Relay® (2.25 L)	-	-	6	**425**	bc	3	bc
4	Agritone® 750 (1.0 L)	-	-	5	**370**	ab	-232	ab
5	Tropotox® (4.0 L) + Agritone® 750 (0.86 L)	-	-	5	**344**	a	-423	a
6	Tropotox® (4.0 L)	-	-	5	**336**	a	-457	a
7	Agritone® 750 (2.0 L)	-	-	5	**375**	ab	-213	ab
8	Agritone® 750 (1.0 L)	Agritone® 750 (1.0 L)	-	5	**428**	bc	58	bc
9	-	Agritone® 750 (2.0 L)	-	2	**399**	abc	-84	abc
10	Paraquat (2.0 L)	-	Agritone® 750 (2.0 L) + Sharpen® (25 g)	5	**474**	c	274	c
11	Tropotox® (4.0 L) + Sharpen® (5 g)	Tropotox® (4.0 L)	-	9	**409**	abc	-129	abc
12	Paraquat (2.0 L)	Paraquat (2.0 L)	Spinnaker® (400 mL)	6	**426**	bc	-60	abc
				Mean	**404**		**-91**	
				P Value	**0.022**		**0.038**	
				LSD (p=0.05)	**76.6**		**421.5**	

Note: Yellow indicates the treatment was amongst the treatments showing the greatest seed yield (p<0.05), or highest Margin-over-Cost. Values followed by the same letter are not significantly different from each other. Chemical active ingredients (a.i.): Argosy® (a.i. 25 g/L diflufenican and 250 g/L bromoxynil Groups 12 and 6), Relay® = Relay® Super S (a.i. 680 g/L 2,4-D ester, Group 4), MCPA = Agritone® 750 (a.i. 750 g/L MCPA, Group 4), Tropotox® = Tropotox® Plus (a.i. MCPB 375 g/L and MCPA 25 g/L, Group 4), Paraquat = Gramoxone® 250 (a.i. 250 g/L paraquat, Group 22) and Sharpen® (a.i. 700 g/kg saflufenacil, Group 14). [1] Average sow thistle control, mean of assessments between 3 August and 14 September 2020 (1 = healthy plant, 10 = Dead). [2] Margin over Cost (MoC): White Clover seed price + $5.50 kg and $20 per chemical application.

Insecticide control options for red clover casebearer

Project Code H19-21

Duration Year 3 of 5

Authors Richard Sim, Murray Kelly, Will Mitchell (PGG Wrightson Seeds)

Location Lincoln, Mid-Canterbury (43° 36’ 49.26” S; 172° 29’ 46.30” E)

Funding Seed Industry Research Centre (SIRC)

Key points

- The first-year red clover seed crop at Lincoln experienced low red clover case bearer (RCCB) pest pressure. Likewise, low numbers of thrips and aphids were observed in seed heads.
- Despite the low insect pest pressure, application of a range insecticide groups, increased red clover seed yield by up to 40%.
- IPM compatible options increased seed yield by up to 15%.
- Given the low incidence of RCCB, the target insect that may have had the most influence on yield remains unclear.

Background

Red clover case bearer (*Coleophora deauratella*) was first reported in New Zealand in December 2016, although subsequent pheromone trapping in 2017-18 reported widespread distribution suggesting the pest had established some years prior to its discovery (Chynoweth *et al*. 2018). Red clover case bearer (RCCB) larvae eat developing seeds, and growers have reported severe seed yield losses when the pest is present.

In 2018-19, as a result of the discovery of red clover case bearer, we began to study strategies for management of this pest, testing insecticide programmes suitable for control and assessing their impact on beneficial insects in the crop (Rolston *et al*. 2019, Faulkner, 2020). However, little research has been conducted on the dynamics of pest and beneficial insects in red clover seed crops in New Zealand. To attract beneficial insects into a crop, planting refugia borders with species like buckwheat (*Fagopyrum esculentum*) and phacelia (*Phacelia tanacetifolia*) is a concept developed for New Zealand vineyards (Wratten *pers. comm*).

This trial investigated RCCB emergence numbers and insecticide options for the control of red clover casebearer larvae which could provide both integrated pest management and broad-spectrum coverage and whether refugia could be established around the crop.

Methods

A red clover seed crop (cultivar Amigain) was established in October 2019, hosted by PGG Wrightson Seeds’ Kimihia Research Farm, in Lincoln. A summary of the management inputs for the crop is outlined in Appendix 1.

The crop was irrigated three times (25 mm per event) after closing. However, only one main flowering period occurred, which ended by mid-February. The crop was desiccated using 3.5 L/ha Reglone® (active ingredient (a.i.) 200 g/L diquat, Group 22) on 8 March 2020 and harvested one week later. Crop closing ocurred at the end of November, early flowers were visible by mid-December and pollinators were active. The entire crop received an application of Minecto Star (500 g/kg pymetrozine and 100 g/kg cyantraniliprole, Groups 9 and 28) which is compatible with integrated pest management (IPM) programmes. The crop reached peak flower on 4 February 2021, and the trial was initiated. The trial design was a randomised complete block with plots measuring 2 m x 12 m. Seven insecticide treatments were tested (Table 1), replicated four times. The trial was sprayed on 4 February 2021 between 06:00 and 06:30 am when environmental conditions were cool (13°C), overcast and no active pollinators could be observed. Standard practice would be for two sprays 10 - 14 days apart, but only one flowering application was made due to the low (<40/week)

RCCB moth counts. The trial was desiccated at the same time as the paddock (Appendix 1) and direct-harvested on 15 March 2021 using a Wintersteiger Classic plot combine, with a cutting width of 1.60 m. Field-dressed samples were air dried prior to re-threshing through a Kurt Pelz stationary thresher. Samples were dressed using an indent cylinder separator to a first-generation seed certification standard. Seed yields were analysed using GENSTAT ANOVA. Differences among insecticides treatment means were identified by Fisher's protected LSD where $P \leq 0.05$.

The activity of male RCCB moths was monitored using an automated smart trap (Trapview : www.trapview.com) with a sex pheromone specific to RCCB [(Z)-7-Dodecenyl acetate 90.9% and (Z)-5-Dodecenyl acetate 0.09%]. The smart trap allows near real-time identification and monitoring of RCCB via a camera and telemetric connection. The trap was deployed from 21 September 2020 until harvest and the pheromone was changed every three weeks and the sticky pad renewed as required. During the season, flower heads were selected and inspected for aphids and thrips.

To attract beneficial insects into the crop a refugia border was planted around the paddock. Buckwheat and Phacelia were direct-drilled at a rate of 6 kg/ha each in a 3 m strip on the 25 October 2020. Prior to sowing, the red clover crop was mown to reduce competition. Due to dry conditions, the seed did not germinate and was re-sown at the same rate on 25 November 2020.

Results

Insecticide efficacy trial. Insecticide application increased ($p \leq 0.001$) red clover seed yield (Table 1). Seed yield was highest ($p<0.05$) when Karate Zeon® (250 g/L lambda-cyhalothrin, Group 3) or Mavrik® Aquaflo (240 g/L tau-fluvalinate, Group 3) was applied with an average seed yield of 145 kg/ha, 40% higher than the nil insecticide treatment at ~100 kg/ha. Movento® OD (150 g/L spirotetramat, Group 23) and Sparta™ (120 g/L spinetoram, Group 5) are considered IPM 'friendly' insecticide options and increased seed yield by 15% compared with the nil insecticide control. Application of Minecto™ Star (500 g/kg pymetrozine and 100 g/kg cyantraniliprole, Groups 9 and 28) and Exeril® (100 g/L cyantraniliprole, Group 28) did not affect seed yield.

Table 1. Seed yield for a first-year red clover (cv. Amigain) crop grown at Lincoln, Canterbury in 2020-21 following application with one of eight insecticide treatments applied on 4 February 2021.

Treatment number	Insecticide application[1]	Application rate (L/ha)	Seed Yield (kg/ha)		Relative Yield
1	Water		103	e[3]	100
2	Lorsban™ EC	0.50	129	bc	125
3	Karate Zeon®	0.04	150	a	146
4	Mavrik® Aquaflo + Actiwett® [2]	0.15	140	ab	136
5	Exeril® + Actiwett® [2]	0.15	109	de	106
6	Movento® OD	0.56	118	cd	115
7	Sparta® + Actiwett® [2]	0.15	117	cd	114
8	Minecto™ Star + Actiwett® [2]	0.15	112	de	109
Mean			**122**		
P value			**<0.001**		
LSD (p=0.05)			**13**		

Note: Yellow indicates the treatments that had the greatest seed yield ($p<0.05$). [1] Lorsban™ EC (500 g/L chlorpyrifos, Group 1); Karate Zeon® (250 g/L lambda-cyhalothrin, Group 3); Mavrik® Aquaflow (240 g/L tau-fluvalinate, Group 3); Exeril® (100 g/L cyantraniliprole, Group 28); Movento® OD (150 g/L spirotetramat, Group 23); Sparta™ (120 g/L spinetoram, Group 5); Minecto™ Star (500 g/kg pymetrozine and 100 g/kg cyantraniliprole, Groups 9 and 28). [2] Actiwett® was applied with the insecticide at 0.05 L/100 L water. [3] Means followed by the same letter are not different at the $\alpha=0.05$ level.

Insect pest numbers

The first RCCB male adult was captured in late September 2020 (Figure 1), with a further 1 – 2 moths caught per week until mid-December (total of 16 caught for the period Sept – Dec 2020). Numbers increased to ~15 per week by the onset of flowering with a maximum of 35 caught in the second week of January 2021. In comparison, for the 2019-20 season, a nearby second-year red clover paddock peaked at 245 during a comparable period (data not presented). Post peak, weekly flight numbers decreased to almost zero in late January which coincided with an insecticide application to the field but excluding the trial. A total of 90 RCCB moths were caught for the 2020-21 season compared to 1180 in the previous 2019-20 season.

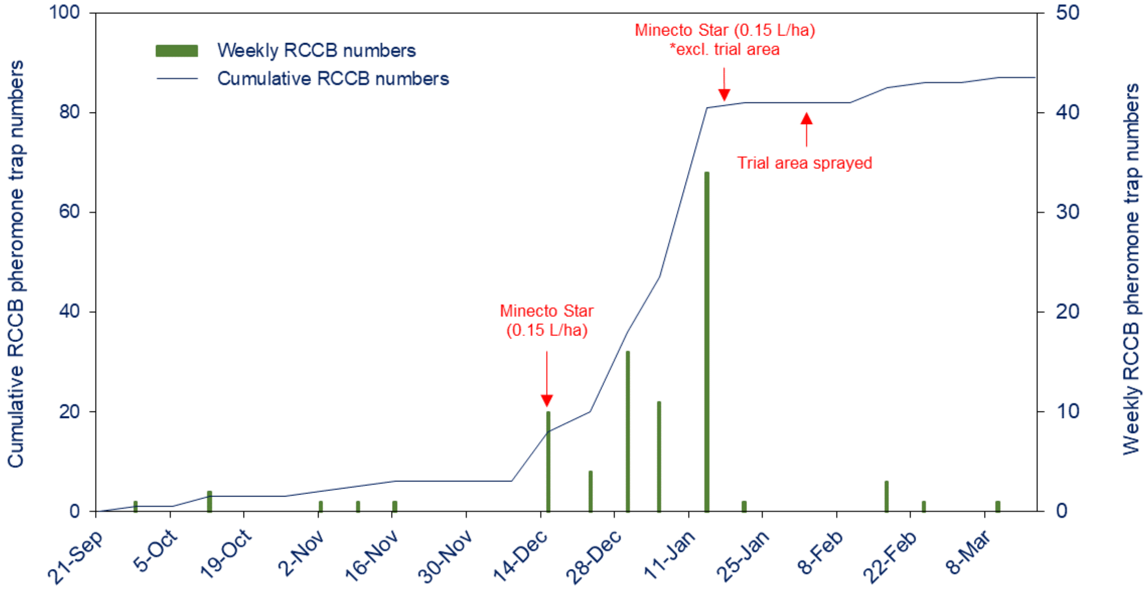

Figure 3 Cumulative and weekly red clover casebearer (RCCB) pheromone trap numbers for a first-year red clover (cv. Amigain) crop grown at Lincoln, Canterbury in the 2020-21 growing season.

Random flower heads were observed for insect pests at peak flower, prior to the establishment of the insecticide trial. Thrip numbers averaged 2 - 3 and aphid numbers averaged 5 - 6 per flower head. Aphids were predominately observed on the uppermost leaves directly under the seed head. Re-inspection two weeks later showed very low numbers of both insect pests which remained low until harvest. No RCCB larvae were observed.

Insect refugia

Given a strong drought at the trial site in 2020-21, lack of water availability, the insect refugia failed. Key learnings included the need to sow into adequate soil moisture as it was impractical to irrigate the crop at that time. The phacelia and buckwheat competed poorly with the red clover and therefore may benefit from red clover desiccation prior to sowing. If sowing occurs before closing, the strips will require fencing off from grazing livestock.

Summary

Red clover case bearer emergence increased rapidly from mid-December, but the total numbers of RCCB in this first- year red clover crop were low compared with numbers historically seen in red clover. Seed yields were increased significantly by the Group 3 insecticides Karate Zeon® and Mavrik® Aquaflo compared with the untreated (by 46 and 36%, respectively). Other more ‘IPM friendly’ chemistries were less effective while Group 28 insecticides had no impact. These differences in impact on yield might have been due to control of pest insects other than RCCB, some of which may have influenced pollination or seed set. The dry spring limited the establishment of refugia to promote beneficial insects around the crop.

References

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Appendix 5. Agronomic management for a first-year red clover (cv. Amigain) seed crop grown at Lincoln, Canterbury for the 2020-21 growing season.

Management	Chemical and application rates	Date
Crop sown		18 October 2019
Herbicide	Preside (65 g/ha) + Uptake oil (1 L/ha)	7 November 2019
Herbicide	Centurion (1 L/ha + Actiwett (0.15 L/ha)	14 July 2020
Herbicide	Gramoxone 250 (1.5 L/ha) Simanex SC (1.5 L/ha)	28 July 2020
Grazing commenced		20 August 2020
Closing		30 November 2020
Insecticide & Fungicide[1]	Minecto Star (0.15 L/ha) Folicur SC (0.22 L/ha)	15 December 2020
Desiccation	Reglone (3.5 L/ha) + Actiwett (0.15 L/ha)	8 March 2021
Harvest		15 March 2021

[1] Fungicide was tanked mix for other crops at the time of spraying.

Weed seed contamination in imported seed lots entering New Zealand

Project code X19-51-00 (SIRC)

Duration Year 2 of 3

Authors Jesse Rubenstein, John Hampton and Phil Hume (Bio-Protection Research Centre, Lincoln University), Christopher Buddenhagen (AgResearch) and Phil Rolston (FAR)

Location N/A

Funding Seed Industry Research Centre (SIRC) and Better Border Biosecurity (B3)

Acknowledgements Ministry for Primary Industries (MPI) (provision of data)

Key points

- Weed seeds were recorded in 1.9% of the 41,610 seed lots imported into New Zealand between 2014 and 2018.
- Among the different crop types, arable had the lowest contamination rate (0.5%) and forage had the highest (12.6%).
- *Chenopodium* spp. (fathen), *Brassica* spp., *Gallium* spp. (cleavers), *Lolium* spp. (ryegrass) and *Polygonum* spp. (wireweed and relatives) were the most frequently occurring weed genera.
- Regulated quarantine weed contamination occurred in only 0.06% of seed lots, with *Sorghum halepense* (Johnson grass) the most commonly occurring quarantine species.
- Johnson grass was only found in vegetable seed lots.
- Vegetable crop seed lots accounted for approximately half of all regulated quarantine weed detections, radish (*Raphanus sativus*) being the most contaminated vegetable crop.
- Larger seed lots were significantly more contaminated and more likely to contain a quarantine weed than smaller seed lots supporting ISTA rules on maximum seed lot weights.

Background

The Ministry for Primary Industries (MPI) is responsible for management of biosecurity risks as they relate to importation of risk goods. This includes the management of seed lots because of the potential pests, such as regulated quarantine weeds, and pathogens they may harbour. MPI inspects every crop seed lot that enters New Zealand and records data on contaminant seeds found within them in their QuanCargo Database. Aside from inspecting every seed lot, MPI also utilises a working sample size five times larger than International Seed Testing Association (ISTA) rules require, which publishes internationally agreed methods for sampling and quality testing of seed. ISTA also sets the rules for maximum seed lot weights based on individual seed size of a crop, which are based on the principles that as seed lot size increases so does both the difficulty to acquire a truly representative sample and the level of contamination. Aside from seed lot size, crop seed-type (arable/cereal, forage, vegetable) can also influence contamination levels, especially in relation to average mass of a seed lot, seed size, handling conditions, wholesale value and farming practices of the crop seed.

Since little is known about the extent of contamination in seed lots entering New Zealand, analysis of interception data could provide biosecurity agencies with information to better target their efforts. Considering that every seed lot imported into New Zealand is inspected, working samples are larger than required by ISTA, and the large number of imported crop species and trading partners, our study is in a unique position to provide an overview of contaminants that move throughout the seed for sowing system.

This study aims to help inform MPI and industry by determining: 1. the most and least contaminated crop types and crop seeds entering New Zealand, including corresponding contamination rates; 2. the most common contaminant seeds; 3) the crop seed, crop type and exporting country most commonly associated with a regulated quarantine weed, and; 4) whether the size of a seed lot is linked to contamination.

Methods

Inspection data from seed lots entering New Zealand between 2014-2018 (41,610 seed lots) were obtained from MPI. Data fields from QuanCargo that were used for analysis included: seedlot ID, crop species, contaminant taxa, country of origin and mass of seed lot. Because contaminants were only reported to the genus level in about one-third of the data, both contaminant seeds and crops seeds were primarily analysed at the genus level. We categorised crop seeds with 65 or more seed lots as either arable, forage, vegetable or mixed-use crops, based on their primary use in New Zealand. Focus crop analysis concentrated on the most contaminated crop seeds, which were defined as those genera with 30 or more records of a contaminant seed (accounted for 74.3% of contaminant records). A list of the most common contaminant species was then categorised based on their status within New Zealand, as either a regulated quarantine weed, non-regulated weed, or seed of a crop other than the one being imported. We compared seed lot weight ($\log_{10}$kg) of non-contaminated and contaminated seed lots for the same crop seed to test whether the size of a seed lot was associated with contamination. Results were derived using a Mann-Whitney *U* test, statistically testing each crop genus individually. A Mann-Whitney *U* test was also used to compare masses between seed lots with a regulated quarantine weed and contaminant-free seed lots.

Results and Discussion

Contamination was rare, occurring in 1.9% of 41,610 seed lots across 1,420 crop seed species. Among the different crop types, arable had the lowest contamination rate (0.5%) and forage had the highest (12.6%). Of the commonly imported crop seeds, *Capsicum, Phaseolus* and *Solanum,* all had contamination rates of zero. Crop seeds *Medicago* (27.3%) and *Trifolium* (19.8%) had the highest contamination rates (Table 1).

Table 1. Focus crops. Commonly contaminated crop seed genera imported into New Zealand based on those with ≥30x records of a contaminant seed for seed imported between 2014 and 2018. Row order based on contamination rate values.

Crop genus (common name)	Percentage of seed lots contaminated	Type of crop seed	Number of seed lots	Primary country of origin
Medicago (lucerne)	27.3	Forage	154	Australia
Trifolium (clover)	19.8	Forage	374	Australia
Glebionis (edible chrysanthemum)	17.9	Vegetable	67	Vietnam
Lolium (ryegrass)	15.9	Forage	560	USA
Festuca (fescue)	9.2	Forage	283	USA
Beta (beet)	8.0	Mixed-use	949	France
Eruca (rocket)	7.1	Vegetable	184	Australia
Raphanus (radish)	5.6	Vegetable	964	Netherlands
Cichorium (chicory)	5.6	Forage	306	Italy
Petroselinum (parsley)	4.6	Vegetable	222	Australia
Brassica (cabbage, mustard)	2.8	Mixed-use	4,028	Australia
Daucus (carrot)	2.7	Vegetable	891	USA
Allium (onion)	2.1	Vegetable	1,367	Australia

Out of 191 genera recorded as contaminants, *Chenopodium* was the most common (Table 2). Regulated quarantine weeds were the rarest contaminant type, only occurring in 0.06% of seed lots. *Sorghum halepense* was the most common quarantine weed and was only found in vegetable seed lots. Vegetable crop seed lots accounted for approximately half of all quarantine weed detections, radish (*Raphanus sativus*) being the most contaminated vegetable crop. Although it is not in the top five countries that New Zealand imports seed lots from, Italy had the most records of a regulated quarantine weed, with eight. Larger seed lots were significantly more contaminated and more likely to contain a quarantine weed than smaller seed lots. These findings support ISTA rules on maximum seedlot weights. Low contamination rates suggest industry practices are effective in minimizing contaminant seeds. By characterising risks associated with crop seed importation, findings could provide biosecurity agencies with information to better target their efforts

Table 2. Common contaminant genera, based on those that were reported ≥30x across all seed lots imported between 2014-2018. Row order based on number of records for all crop seeds.

Contaminant genus	Number of records for all crop seeds	Focus crops only (number of records)
Chenopodium	103	*Trifolium* (17), *Brassica* (10), *Lolium* (8), *Medicago* (6), *Daucus* (4), *Glebionis* (4), *Cichorium* (3), *Eruca* (3), *Festuca* (3), *Petroselinum* (2), *Raphanus* (1)
Brassica	80	*Raphanus* (16), *Brassica* (14), *Allium* (5), *Trifolium* (5), *Daucus* (4), *Lolium* (4), *Medicago* (4), *Petroselinum* (4), *Festuca* (3), *Beta* (2), *Eruca* (2), *Glebionis* (2)
Galium	78	*Brassica* (26), *Raphanus* (13), *Beta* (8), *Lolium* (5), *Glebionis* (4), *Trifolium* (3), *Allium* (2), *Daucus* (2), *Cichorium* (1), *Festuca* (1), *Medicago* (1), *Petroselinum* (1)
Lolium	67	*Trifolium* (18), *Medicago* (9), *Brassica* (8), *Daucus* (4), *Festuca* (3), *Lolium* (3), *Beta* (2), *Raphanus* (2), *Allium* (1), *Cichorium* (1), *Eruca* (1), *Glebionis* (1), *Petroselinum* (1)
Polygonum	63	*Lolium* (20), *Medicago* (15), *Brassica* (8), *Daucus* (6), *Trifolium* (6), *Allium* (1), *Cichorium* (1), *Festuca* (1), *Glebionis* (1), *Petroselinum* (1)
Fallopia	61	*Beta* (24), *Raphanus* (15), *Brassica* (4), *Glebionis* (3), *Lolium* (2), *Allium* (1), *Petroselinum* (1)
Trifolium	60	*Trifolium* (15), *Medicago* (14), *Festuca* (5), *Lolium* (5), *Beta* (2), *Brassica* (1), *Cichorium* (1), *Daucus* (1), *Eruca* (1), *Glebionis* (1), *Raphanus* (1)
Echinochloa	54	*Lolium* (9), *Brassica* (6), *Daucus* (6), *Glebionis* (4), *Trifolium* (3), *Raphanus* (2), *Allium* (1)
Persicaria	51	*Brassica* (11), *Lolium* (10), *Trifolium* (5), *Glebionis* (4), *Cichorium* (3), *Eruca* (3), *Festuca* (3), *Medicago* (3), *Daucus* (2), *Petroselinum* (1), *Raphanus* (1)
Triticum	51	*Beta* (17), *Raphanus* (12), *Brassica* (7), *Lolium* (2), *Eruca* (1), *Glebionis* (1)
Rumex	43	*Medicago* (8), *Lolium* (7), *Trifolium* (7), *Eruca* (5), *Petroselinum* (3), *Allium* (2), *Brassica* (2), *Festuca* (2), *Daucus* (1), *Raphanus* (1)
Amaranthus	42	*Trifolium* (8), *Brassica* (6), *Daucus* (2), *Eruca* (2), *Glebionis* (1), *Lolium* (1), *Medicago* (1), *Raphanus* (1)
Poa	32	*Lolium* (18), *Trifolium* (6), *Festuca* (5), *Allium* (1)

Summary
Data were extracted from MPI's QuanCargo data base for 41,610 seed lots imported into New Zealand between 2014 and 2018. Weed seeds were recorded in 1.9% of these seedlots.

Forage crops had the most frequent contamination, especially *Medicago*, *Trifolium*, and *Lolium* (ryegrass). Arable crops had the least frequent contamination. C*henopodium* spp. (fathen), *Brassica* spp., *Gallium* spp. (cleavers)*, Lolium* spp. (ryegrass) and *Polygonum* spp. (wireweed and relatives) were the most common occurring weed genera.

Regulated quarantine weed contamination occurred in only 0.06% of seed lots, with *Sorghum halepense* (Johnson grass) was the most commonly occurring quarantine species. Seed lots from Italy had more quarantine weeds than other countries. Larger seed lots had more contamination than smaller seed lots.

Radish seed crop establishment with strip-tillage

Project code	X20-02
Duration	Year 1 of 2
Authors	Phil Rolston, Richard Chynoweth, Owen Gibson (FAR), Allister Holmes (FAR and Lincoln AgriTech) and John Hampton (Lincoln University)
Location	Leeston, Mid Canterbury (43° 46’ 49.99” S; 172° 16’ 10.57” E)
Funding	Rural Professional Fund, Our Land and Water – National Science Challenge; Seed Industry Research Centre (SIRC)
Acknowledgements	David Birkett (trial host), NZ Arable (weigh wagon service), Wadia Kandula (Bio-Protection Research Centre**,** Lincoln University)

Key points

- Establishment of a radish seed crop using full cultivation or strip-till resulted in no difference in seed yield.
- Initial growth of radish was slightly behind in the strip-till compared with full cultivation.
- There were fewer white blister lesions in the strip-till rows compared to full cultivation.

Background

In New Zealand, the industry standard for preparation of many arable crops, including radish, involves moving the complete soil mass in the top 15 cm using a plough, discs, and rippers etc in order to create a fine seedbed to achieve consistent seed to soil contact, which provides even germination and emergence. All of these methods create significant disturbance to soil aggregates. However, many crops do not necessarily require a fine seed bed, and therefore can be established using reduced tillage techniques. These techniques have many benefits, including reducing soil disturbance and damage to soil aggregates, retention of soil moisture, and reduction of soil erosion. Strip-tillage has been used to establish maize and other crops grown in wide rows where the in-between row space can be left undisturbed. Potential benefits include:

- Reduced energy and expense during cultivation, because only part of the soil is tilled and some primary and secondary tillage is eliminated.
- Reduced soil erosion and conserved soil moisture, because 50% of the soil remains covered with crop residue throughout the year.
- Crop yields that are similar or higher, compared with other tillage systems.

Radish seed crops are established in 50 cm row spacings. Assuming 10 cm is required to create a fit for purpose seedbed, 80% of the soil could potentially be left undisturbed. This project investigated the impacts on seed yield of radish established via strip-till compared with yields using full cultivation. A small survey of growers using strip-till for seed crop establishment was also completed to understand perceptions and logistics of using this technique.

Methods

The paddock had previously grown green feed oats, which were planted 12 April 2020 and terminated with glyphosate on 17 August 2020 following grazing. The oats were grazed multiple times over winter, leaving a layer of plant material covering the soil at the end of grazing. Base fertiliser was broadcast and incorporated in with cultivation or strip-till. The trial was sown in a European round radish with the female line, SPS11030FM and the males SPS11030M, in a ratio of 6 female rows and 2 male rows in 50 cm wide rows. Plots consisted of female beds (12 rows each 50 cm apart) flanked on one side by a male bed (four rows each 50 cm apart). Plots were the length of the field. The trial design was a randomized block design with four replicates.

The full cultivation area was disced, Maxi-Tilled for Treflan® (active ingredient (a.i.) 480 g/L trifluralin, Group 3) incorporation, base fertiliser applied and disced and Cambridge rolled before planting. The strip-tillage utilised a Kverneland Kultistrip machine with the first strip-till pass on 1 September, followed by a second pass on 10 September. The site was 'Cambridge rolled' before drilling. Treflan® was applied to this area at the same time as full cultivation but not incorporated.

Drilling used the same precision planter for both treatments targeting 9 seeds/m of drill row. Standard crop management was applied to both conventional and strip-till radish by the grower for the rest of the season. Pre-harvest, the crop was desiccated using 4.5 L/ha Reglone® (a.i. 200 g/L diquat, Group 22) plus 1.5 L/ha Uptake™ spraying oil on 4 April.

Radish seedling establishment was assessed on 23 October 2020, 5.5 weeks after drilling, by counting the number of radish seedlings in one metre of row at five locations per plot. Canopy height was also assessed at five points per plot on 24 December 2020. The number of flowering branches per plant was counted *in-situ* on five plants per plot at the same time.

Neutron probes were placed in three places in each plot (24 probes) by Aqualink with weekly measurements made from 25 November 2020 until the week prior to harvest. Soil moisture was measured at five depths and summarised into three bands: 0-30 cm, 30-40 cm and 40 cm-60 cm.

Weed numbers were assessed in 1 m^2 quadrats on 24 December 2020 at five locations in each plot. The dominant weed was shepherd's purse (*Capsella bursa-pastoris*). White blister disease (*Albugo candida*) was assessed on 26 February 2021 by counting the number of infections in 10 quadrats, each 1 m^2 per plot.

The crop was combine-harvested on 9 May 2021 with a Case IH, 'Axial Flow' combine. The crop was machine harvested on 9 May 2021. Each plot was harvested separately, a distance of 194 m by 3 m wide (one 6 row female bed) and the yield assessed by weighing the harvested seed in a weigh wagon. The machine-dressed seed yield was calculated assuming a 20% seed dressing loss and adjusted to include the width of the area occupied by the male rows.

Six growers using strip-till for seed crop establishment were surveyed via telephone in May 2021.

Results and Discussion

Establishment trial

There was no difference in the number of seedlings established six weeks after planting or on weed density in late December between full cultivation and strip-till treatments (Table 1). At the start of flowering (24 December), the strip-till plants were shorter and had fewer flower branches (Table 1). This is in line with the grower's observation that the strip-till crop was slower in growth than the fully cultivated crop. It is probable that the soil in the fully cultivated area was slightly warmer and thus allowed for better early season growth.

There were fewer white blister lesions in the strip-till treatment compared with full cultivation (Table 1), however the overall number of lesions was low suggesting the grower's fungicide programme was adequate to control the disease. None of these differences resulted in seed yield differences between the two establishment practices with a mean yield of 850 kg/ha.

In this irrigated crop, the average soil water deficit was slightly less (4 mm) in the fully cultivated plots. This was associated with a difference at the first readings (Table 2). The maximum deficits between the two establishment practices were not significantly different.

Table 1. Seedling numbers 5.5 weeks after sowing, plant height, weed density, number of flowering branches per plant, white blister lesions and seed yield for fully cultivated and strip-till radish seed crops at Leeston in 2020-21.

Treatments	Seedling (m^2)	Height (cm)	Weeds (m^2)	Flower branches (per plant)	White blister lesions (m^2)	Seed yield (kg/ha)
	(23 October)	(24 December)			(26 February)	(9 May)
Full cultivation	17.2	976	3.9	11.1	9.8	845
Strip-Till	16.5	835	2.9	8.7	7.4	860
LSD (p=0.05)		**136**		**2.3**	**1.4**	
P value	**0.52**	**0.046**	**0.53**	**0.048**	**0.011**	**0.85**
Significance	**NS**	*****	**NS**	*****	******	**NS**

Table 2. Maximum and average soil moisture deficit between 25 November 2020 and 16 February 2021 for a radish seed crop grown with irrigation at Leeston 2020-21 following full cultivation or strip-till establishment.

Establishment technique	Maximum deficit (mm)	Average deficit (mm)
Full cultivation	25.4	12.6
Strip-tillage	28.4	15.6
LSD (p=0.05)		**1.4**
P value	**0.32**	**0.006**

Grower survey results

A survey of six growers using strip tillage to establish seed crops identified the following:

1. Most respondents were relatively new to strip-tillage, only using the technology for the past one or two seasons. One respondent had been using strip-tillage for over 10 years.
2. A large range of crops were currently drilled with strip-tillage but most are wide-rowed seed crops such as: carrots, red beet, spinach, radish, sunflower, maize, kale and Chinese mustard.
3. Strip-tillage has allowed farmers to cultivate into a previous season's grass seed crop with minimal soil disturbance. This would previously involve a more invasive cultivation technique to prepare a suitable seed-bed. One hundred percent of farmers surveyed noted this as a fundamental advantage when considering strip-tillage over conventional minimal tillage systems.
4. Strip-tillage has been proposed to offer many other potential benefits for a multitude of different crops. The information received from the survey highlighted some key mutual benefits received from strip-tillage amongst the growers. Maintaining soil structure and reducing compaction from livestock over winter was a very dominant response to the survey. Other proposed benefits strip-tillage can offer were protecting soil biology and structure while reducing wind and water erosion, reduction in compaction from reduced machinery passes on the paddock, and less horsepower required as only a fraction of the total area is cultivated. These last two benefits also lead to a reduction in machinery running costs and carbon emissions.
5. Strip-tillage equipment comes in a variety of models and cultivation arrangements. In our survey, two commercial strip-tillage machines were commonly used. The Kverneland

Kultistrip, which is a dedicated strip-tillage system with changeable row spacing of 45-80 cm. Cultivation depth can be altered (10-30 cm). Seed drilling is a separate operation. The Mzuri strip-tillage drill is a multi-role tillage and seed drill. It has a pre-cultivating cutting disc and cultivating tine to work the area to a level below the seed bed. Both machines are capable of band fertiliser application with granules of uniform size and offer many attachments to add extra capabilities. Di-Ammonium Phosphate (DAP) was the preferred fertiliser at establishment; rates ranged from 150-250 kg/ha. The majority of respondents used pre-season soil tests to determine the fertiliser used and the applied rate.

6. The type of strip-tillage system used dramatically changed the paddock management to produce an adequate seed-bed. Respondents that use the Kverneland Kultistrip all agreed that to get a good seed-bed it was imperative to spray out grass paddocks with herbicide. Typically, glyphosate is broadcast-sprayed at least six weeks prior to cultivation. Only one respondent had used banded herbicide application in the past. Pre-strip till sward termination with glyphosate allows the root mass to break down to allow soil shattering to produce an appropriate seed-bed. The Mzuri system is generally different, with most respondents answering that if the paddock is left sprayed-off for too long the drill can kick out clogs which then need to be Cambridge-rolled after seeding. The number of cultivation passes needed to prepare a satisfactory seedbed is dependent on the soil condition and it is a risk to believe that strip-till is only a one pass system.
7. Planning and preparation are key to a good strip-tillage experience. Making sure all factors have been considered prior to cultivation will allow for good establishment. This is paramount for success. Understanding the potential problems before they arise will ultimately lead to a favourable strip-tillage experience, for example ‘increased slug pressure’. When relying on contractors a new range of problems exist, e.g. making sure the GPS lines up with drilling and the strip-till is crucial. Problems have arisen from using different precision agriculture self-steer systems. This can result in the seed drilled outside or on the edge of the strip-till.
8. The biggest limitation to using strip-tillage is machinery cost. It is unrealistic to buy a strip-till capable drill or cultivator especially on a smaller farm which has limitations on the variety of crops it can establish. As the practice becomes more widespread and more contractors are offering strip-tillage, costs will reduce. It is important for users to understand that strip-tillage is not a quick turnaround system so good planning and preparation is essential.
9. All of the farmers questioned in this survey replied that they would continue to use strip-tillage in their farm operation. These farmers also commented that there is an adequate number of contractors offering strip-tillage and cost was not a drawback when all the potential benefits are considered.

Summary

Initial growth of radish was slightly behind in the strip-till compared to full cultivation. However, there were fewer white blister lesions in the strip-till rows (7.4 lesions/m^2) compared to full cultivation (9.8 lesions/m^2). These differences did not translate into yield differences, with no difference in radish seed yield between cultivated (845 kg/ha) and strip-till (860 kg/ha) treatments.

One potential benefit of strip-till for row crops is the ability to band incorporate fertiliser close to the crop row. The equipment used in this trial was not set up to band fertiliser, but future work should include this as an option.

A survey of six seed growers using strip-tillage, showed a wide range of row-crops have been grown with strip-till. Machinery costs are the biggest limitation and growers using strip-till are using contractors. Often strip-tillage and seed drilling are two separate steps and getting compatibility between GPS systems to align drill rows to strips is an issue. The ability to band fertiliser with strip-till drilling would potentially improve fertiliser efficiency and/or reduce fertiliser inputs.