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Arable Update

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Fungicide strategies for downy mildew control

Year 1 of 5 trial results (2023-24 season)

Key points

- Moderate cocksfoot downy mildew pathogen pressure was observed in this fungicide evaluation trial, influenced by favourable early-season weather conditions and reduced by hot, dry weather during seed filling.
- Phoenix® Fungicide (folpet, Group M4) and Foschek® (phosphorous acid, Group P07) effectively reduced pathogen symptoms
- Ridomil® Gold MZ WG (metalaxyl-M (mefenoxam) + mancozeb, Group 4 + Group M3), Gem® Fungicide (fluazinam, Group 29), and Curfew® (cymoxanil, Group 27) showed limited efficacy.
- Foschek® reduced seed head bleaching and may offer some level of control against the cocksfoot downy mildew pathogen, warranting further research.
- Economic analysis showed no differences in margin-over-cost (MoC) values among fungicide treatments.

Background

Since the 2018, downy mildew has emerged as a significant foliar disease affecting cocksfoot (*Dactylis glomerata*) seed crops in New Zealand. The putative pathogen responsible for this disease is believed to be *Sclerophthora cryophila*, a biotrophic oomycete. Prior to 2018, downy mildew had not been reported in New Zealand's cocksfoot seed producing areas suggesting that *S. cryophila* may have been present but undetected for an extended period of time. The earliest documented report of *S. cryophila* affecting cocksfoot dates back to 1948, when Jones (1955) first observed symptoms resembling frost damage in affected field plots in Canada. To date, despite cocksfoot's widespread cultivation and presence in both cultivated and wild grass environments globally, instances of *S. cryophila* infecting cocksfoot have not been reported since its initial detection (Crouch *et al*., 2022). Although *S. cryophila* is considered the likely pathogen responsible for cocksfoot downy mildew in New Zealand, definitive identification has not yet been achieved, pending further validation through molecular sequencing. Therefore, throughout this report, the term "cocksfoot downy mildew pathogen" will be used to refer to this pathogen.

Cocksfoot downy mildew pathogen primarily infects susceptible cocksfoot plants via the leaves, leaf sheath and stems, with the resulting damage causing seed yield losses, especially when conditions are cool (<15°C) and moist (Jones, 1955). Generally, downy mildew has presented on susceptible cocksfoot plants with light yellow to tan lesions which can appear as bands on leaves and reproductive stems (peduncles) a few days after flowering (GS 60- 69) (Harvey & Braithwaite, 2022). Over time, these lesions expand, eventually causing the upper stem and seed heads to bleach, leading to reduction in the size of seeds or total seed loss (Jones, 1955). Downy mildew has primary and secondary infection stages, which are disseminated by infection structures called sporangia (spores) that are spread via rain splash and release motile zoospores that can infect host tissue via the stomata when in the presence of free water. Provided conditions are conducive, these sporangia will be produced on sporangiophores nocturnally (under darkness) for a just a few hours in the early morning (Crouch *et al*., 2022). The primary infection is expected to occur each year, but the secondary infection, which can cause significant damage, typically takes hold during the spring and summer months when the weather is wet.

The cocksfoot downy mildew pathogen is caused by an oomycete, an organism that is fungal-like, but taxonomically, is not classified as part of the fungal kingdom which contains "true fungi". Consequently, fungicides effective against true fungal diseases that affect cocksfoot like leaf fleck (*Mastigosporium rubicosum*), brown leaf spot (*Cercosporidium graminis*), and rusts (Uromyces and Puccinia spp.) are ineffective against this pathogen. While several fungicides have shown efficacy against downy mildew pathogens in crops like grapes, onions, and potatoes (Salcedo *et al*., 2021), there is limited information on the effectiveness of these active ingredients against graminicolous downy mildews, including the pathogen responsible for cocksfoot downy mildew. Over the past three years, The Foundation for Arable Research (FAR)-Seed Industry Research Centre (SIRC) trials (Chynoweth *et al*., 2022, 2023) have identified several fungicides from different Fungicide Resistance Action Committee (FRAC) mode of action (MOA) groups that can suppress this disease. These include phthalimides (Group M4), such as folpet (Phoenix® Fungicide) and captan (Captan 600 Flo), phenylamides (Group 4), such as metalaxyl-M (mefenoxam) in Ridomil® Gold MZ WG and SL and phosphonates (Group P07), such as phosphorous acid (Foschek®). While these products have been shown to be efficacious against the cocksfoot downy mildew pathogen, there is still a need to further investigate new chemistries specifically targeting oomycetes to enhance control and mitigate resistance development. This report outlines a fungicide evaluation field trial conducted during the 2023-24 growing season, evaluating the efficacy of a range of fungicides targeting oomycetes for managing cocksfoot downy mildew pathogens.

Methods

A small plot trial was established during the 2023-24 season in a six-year-old cocksfoot seed crop (cv. Savvy) in Methven (-43.571590, 171.676552). Table 1 presents the trial's 16 treatments, which were arranged in a complete randomised experimental design with four replicates. The design incorporated two blocking factors (replicate and block) and featured doubly resolvable rows and columns. Treatment plots within each replicate were 2 m wide and 12 m long (24 m2). All treatments containing Curfew® or coded product FARF2401 were applied with Arma™ (modified alkylamine polymer) at a rate of 1 mL/L or Hasten™ (704 g/L ethyl and methyl esters of canola oil fatty acids with 196 g/L non-ionic surfactants) at a rate of 0.5 L/100 L water. A list of the products included within each treatment is shown in Table 1. Treatments 3-16 were applied in addition to standard fungicide programme applied in Treatment 2 i.e. 1.5 L/ha Phoenix® applied at GS 33 was also applied with 1 L/ha Opus® and 0.75 L/ha of AMISTAR®. All paddock management was as per the host farmer throughout the season with the exclusion of any fungicides being applied to the trial site.

Treatments were applied at four different timings, either at second plant growth regulator (PGR) timing when 50% of tillers with node 3 at least 2 cm above node 2 (Zadocks growth stage (GS) 33) (Zadoks *et al*., 1974) (T1; 3 November 2023), 50% of tillers were at end of emergence (GS 59) (T2; 1 December 2023), 50% of tillers at full flowering (GS 65) (T3; 14 December 2023) or 14 days after flowering (GS 69) (T4; 28 December 2023). Conditions at the timing of most applications at both trial sites were damp and calm with no wind. All treatments were applied at all application timings using a backpack type sprayer unit equipped with a 12-volt Flojet pressure pump and 2 m handheld spray boom fitted with 6 x 110 015 AIXR Teejet® nozzles at 33 cm spacing delivering a water rate of 270 L/ha at an operating pressure of 280 kPa.

Assessments of disease incidence and crop greenness were conducted at nine timings during the growing season. The severity of cocksfoot downy mildew pathogen infection on individual cocksfoot plants was determined by completing a quantitative disease severity part assessment at five different assessment timings. For each diseased part assessment, green leaf area and percentage of top four leaves, stem and head area infected by cocksfoot downy mildew pathogen or leaf fleck lesions (*Mastigosporium rubicosum*) were assessed on a scale of 0 to 100%, where 0% indicated no area was affected by disease and 100% was all of plants affected by disease. The first and third assessments, were conducted on the 1 December 2023 and 4th January 2024, respectively. In these assessments, we evaluated only 20 tillers that were collected randomly from across the whole trial. In the second, fourth and fifth assessments, conducted on the 11 December 2023, 10 and 20 January 2024, respectively, 10 tillers per plot were evaluated. The progression of disease severity was assessed using a global ordinal scale based on the severity estimation method outlined by Bock *et al*. (2020). This scale evaluated the percentage of plants affected by fungal and oomycete symptoms, as well as the percentage of tillers exhibiting head bleaching. The assessment involved a subjective visual approach, where a rating of 0% indicated no affected plants and 100% indicated all plants were affected by disease. Evaluations were conducted on the 4th January 2024 (7 days after Timing 4 application), 8th January 2024 (11 days after Timing 4), 12 January 2024 (15 days after Timing 4), 16 January 2024 (19 days after Timing 4), and 19 January 2024 (22 days after Timing 4). Treatment plots were assessed for greenness by estimating the greenness of treatment plots using a subjective visual assessment of plant greenness within each treatment plot, where 0% indicated no plants with green leaf area and 100% indicated that all plants had full green leaf area. Greenness assessments were completed on the 4 January 2024 (7 DAA – T4), 8th January 2024 (11 DAA – T4), 10 January 2024 (13 DAA – T4), 12 January 2024 (15 DAA – T4), 16 January 2024 (19 DAA – T4) and 19 January 2024 (22 DAA – T4). Seed yield was obtained by windrowing plots using a modified John Deere plot windrower with a 1.8 m cut width on the 21 January 2024 and harvesting all treatment plots with a Wintersteiger Classic plot harvester on the 30 January 2024. Machine dressed yield and percentage dressing loss were all determined post-harvest.

All analyses of trial data were conducted using R software programming language (R Core Team, 2024). The Akaike Information Criterion (AIC), which estimates prediction error, and thus the relative quality of statistical models, was computed using the R packages 'AICcmodavg' (Mazerolle, 2020) and 'VGAM' (Yee, 2010) for each variable. Models with lowest AIC values (AICc) and fewer parameters (K) were considered to have the best fit. For the analysis of visual estimate scores (including disease, greenness, and seed head bleaching), a two-way linear mixed-effects model was fitted using the residual maximum likelihood (REML) method. Treatment and replicate were included as fixed effects, while row and other random factors, as appropriate for specific variables, were treated as random effects. Disease severity data from quantitative assessments which included all tiller parts were analysed using a two-way linear mixed-effects model with the REML procedure. Treatment and replicate were included as fixed effects, while row, leaf number, and other factors specific to each variable were treated as random effects. Harvest variables (machine dressed yield, dressing loss and margin-over-cost (MoC)) were analysed using a two-way linear model with treatment and replicate as fixed effects. All analyses were carried out using the R packages 'stats' and 'lme4' (Bates *et al.*, 2015). The adjusted means, least significant difference (LSD), and coefficient of variation (CV) were generated using the R package 'predictmeans' (Luo *et al.*, 2014). The LSD test was not performed for any variables that had a non-significant P-value (P≥0.05) after performing an analysis of variance (ANOVA). To calculate the MoC, the treatment cost per hectare and cost per application were subtracted from the revenue generated per hectare for each plot. This calculated amount was then further subtracted from the cost per hectare of the untreated control. Calculations were based on a grower's cocksfoot seed price of $5.25/kg.

Overall trial details

The paddock was grazed by sheep through the autumn and winter of 2023 with the closing date for the paddock being 20 May 2023. During the year of the trial (2023-2024) no fungicide products were applied within the trial site. A full description of paddock management details is shown in the table below:

Activity	Date	Product/Rate
Fertiliser	17 Apr 2023	150 kg/ha SustaiN® (N = 45.9)
	9 Aug 2023	150 kg/ha Cropzeal 16N (NPKS = 15.2-8-10-9.6)
	22 Sep 2023	100 kg/ha SustaiN® (N = 45.9)
	19 Oct 2023	150 kg/ha SustaiN® (N = 45.9)
Plant Growth Regulators	18 Oct 2023	1 L/ha Stabilan® 750SL (750 g/L chlormequat-chloride)
		0.3 L/ha Trexel® (250 g/L trinexapac-ethyl)
	31 Oct 2023	1.5 L/ha Stabilan® 750SL (750 g/L chlormequat-chloride)
		0.2 L/ha Trexel® (250 g/L trinexapac-ethyl)
Herbicides	27 June 2023	1.25 L/ha Atraflow™ (500 g/L atrazine, Group 5 Herbicide)
		0.8 kg/ha Karmex® 900 (900 g/kg diuron, Group 5 Herbicide)
	3 Oct 2023	1.5 L/ha Agritone® 750 (750 g/L MCPA, Group 4 Herbicide)
		3 g/ha Mustang® (600 g/kg metsulfuron-methyl, Group 2 Herbicide)
Fungicides	11 Nov 2023	1 L/ha Opus® (125 g/L epoxiconazole, Group 3 Fungicide)
		1.5 L/ha Phoenix® Fungicide (500 g/L folpet, Group M4 Fungicide)
	7 Dec 2023	0.75 L/ha AMISTAR® (250 g/L azoxystrobin, Group 11 Fungicide)
		1 L/ha Prosaro® (125 g/L prothioconazole + 125 g/L tebuconazole, Group 3 Fungicide)
		2.5 kg/ha Ridomil® Gold MZ WG (40 g/kg metalaxyl-M (mefenoxam), Group 4 Fungicide + 640 g/kg mancozeb, Group M3 Fungicide)
	28 Dec 2023	0.4 L/ha AMISTAR® (250 g/L azoxystrobin, Group 11 Fungicide)
		1.5 L/ha Phoenix® Fungicide (500 g/L folpet, Group M4 Fungicide)
		1 L/ha Stellar® (125 g/L epoxiconazole, Group 3 Fungicide)
Insecticides	1 May 2023	50 mL/ha Dimilin® 2L (240 g/L diflubenzuron, Group 15 Insecticide)
Adjuvant	1 May 2023	50 mL/ha Actiwett® (935 g/L alcohol ethoxylate)

Results and Discussion

Visually, cocksfoot downy mildew pathogen pressure across this trial was considered to be moderate, with this pressure being lower compared to a similar trial conducted in 2021-22 (Chynoweth *et al*., 2022) but higher than another trial in 2022-23 (Chynoweth *et al*., 2023). This fluctuation is likely attributable to weather conditions; specifically, the wet and cool conditions that occurred at the site between November and December 2023, which would have favoured downy mildew. These conditions were followed by dry and hot weather from mid to late January 2024 which would have reduced infection risk during seed filling, potentially limiting pathogen symptom severity as shown in the seed head bleaching scores (Table 1) which do not exceed 50%.

The machine-dressed seed yield (Table 2) of Treatment 2, the commercial standard, did not differ ($P \geq 0.05$) from most treatments using oomycete-targeting products. This outcome indicates that the influence of downy mildew on realised seed yield was less pronounced than previously reported in similar studies (Chynoweth *et al*., 2022). This finding is further supported by the dressing loss data (Table 2) where the commercial standard did not differ from the values recorded in the untreated control plots (Treatment 1) or in plots treated with products containing active ingredients targeting oomycetes. While the absence of differences among other treatments does not contribute new insights into the optimal timing for controlling cocksfoot downy mildew pathogen, it does support earlier findings from trials conducted during the 2021-22 (Chynoweth *et al*., 2022) and 2022-23 (Chynoweth *et al*., 2023) seasons. Specifically, treatments using Phoenix® (a.i folpet, Group M4) applied at various growth stages consistently resulted in the severity of cocksfoot downy mildew pathogen symptoms (both quantitative and visual plot-based estimates) being lower compared to most other treatments. This conclusion is supported by the disease severity assessment data presented in Table 1. For example, treatments utilising Phoenix® alone at a rate of 1.5 L/ha (Treatments 3, 4 and 5) or in a tank mix with 2 kg/ha of Ridomil® Gold MZ WG (Treatment 8) exhibited reduced visual symptoms of the cocksfoot downy mildew pathogen on tiller leaves and stems, accompanied by moderate greenness scores.

There were also some other key products that were identified to have promising levels of activity on cocksfoot downy mildew pathogen. For example, Foschek® (phosphorous acid, Group P07) effectively reduced stem and head bleaching symptoms, showing promise for future trials despite plots where this treatment was applied having moderate visual leaf symptom levels throughout the assessment period. Captan 600 Flo (captan, Group M4) also performed well, reducing leaf symptoms and maintaining greenness, further highlighting the potential of the Group M4 fungicides. Conversely, treatments containing Ridomil® Gold MZ WG applied solo, Gem®Fungicide, or Curfew® showed higher levels of leaf and seed head bleaching, indicating limited efficacy of their active ingredients (metalaxyl-M and mancozeb, fluazinam, and cymoxanil, respectively). This effect was evident in Treatments 8 and 9, where the addition of Ridomil® Gold MZ WG to Phoenix® failed to provide an additive improvement in disease control compared to treatments where Phoenix® was applied alone. The lack of enhanced efficacy when tank-mixing Ridomil® Gold MZ WG with Phoenix® indicates that, in this trial, there was no synergistic benefit from the inclusion of metalaxyl-M or mancozeb, which belong to fungicide mode of action Groups 4 and M3, respectively. These results highlight the importance of selecting effective fungicides and optimising application timing for managing cocksfoot downy mildew pathogen. Further research is required to determine whether the reduced efficacy observed in this trial is due to the intrinsic properties of the active ingredients or environmental factors affecting application timing.

The MoC for fungicide treatments was positive, however, there was no difference observed in MoC values ($P \geq 0.05$), indicating that none of the treatments provided an economic advantage relative to each other (Table 2 & Table A1). Treatment 10 (Foschek, 5 L/ha) applied at ear emergence and flowering, exhibited the highest MoC of $1800/ha, indicating robust economic performance. This result can likely be attributed to its lower cost per litre ($12.3/L) and minimal seed head bleaching, likely influenced by the mode of action of phosphorous acid. In contrast, treatments such as Treatment 7 (Ridomil® Gold MZ WG, 2 kg/ha) and Treatment 13 (Gem®, 750 mL/ha), applied twice at ear emergence and flowering, showed lower MoC values of $546/ha and $677/ha, respectively. Overall, treatments with higher fungicide application costs did not consistently yield higher MoC, underscoring the importance of selecting cost-effective fungicide strategies based on disease pressure and timing.

Table 1. Mean cocksfoot downy mildew pathogen symptoms on leaves, stems and seed heads as well as leaf greenness per tiller recorded on 10 January 2024, along with mean visual estimate scores of greenness and overall disease (all fungal and oomycete diseases) recorded on 12 January 2024, in cocksfoot (*Dactylis glomerata*) (cv. Savvy) plots treated with 15 different fungicide treatments. The trial was conducted near Methven during the 2023-24 season. Cells highlighted yellow show the top statistical group (most effective treatments) based on least significant difference (LSD) (P≤0.05) for each presented variable.

Trt No	Fungicide names**, rates (L/ha) and timing: 2nd Growth Reg (GS 33) (3 Nov 2023)	Ear Emergence (GS 59) (1 Dec 2023)	Flowering (GS 65) (14 Dec 2023)	Flowering + 14 days (GS 71-79) (28 Dec 2024)	Mean downy mildew leaf symptoms per tiller (0-100%)	Mean downy mildew stem symptoms per tiller (0-100%)	Mean seed head bleaching per tiller (0-100%)	Mean leaf greenness per tiller (0-100%)	Mean estimated disease score (0-100%)	Mean estimated greenness score (0-100%)
1	Untreated	-	-	-	84	30	45	38	67	37
2	Opus® (1 L/ha) + AMISTAR® (0.75 L/ha)	Proline® (0.8 L/ha) + SEGURIS®Flexi (0.6 L/ha)	Proline® (0.8 L/ha) + SEGURIS®Flexi (0.6 L/ha)		52	19	27	42	50	52
3	Phoenix® (1.5 L/ha)	Phoenix® (1.5 L/ha)			30	7	15	64	25	82
4		Phoenix® (1.5 L/ha)	Phoenix® (1.5 L/ha)		43	9	22	50	25	80
5	Phoenix® (1.5 L/ha)	Phoenix® (1.5 L/ha)	Phoenix® (1.5 L/ha)		34	7	16	61	15	90
6			Phoenix® (1.5 L/ha)	Phoenix® (1.5 L/ha)	52	17	24	42	35	65
7		Ridomil®WG (2 kg/ha)	Ridomil®WG (2 kg/ha)		55	15	40	37	35	67
8		Phoenix® (1.5 L/ha) + Ridomil®WG (2 kg/ha)	Phoenix® (1.5 L/ha) + Ridomil®WG (2 kg/ha)		32	10	15	62	22	77
9			Phoenix® (1.5 L/ha) + Ridomil®WG (2 kg/ha)	Phoenix® (1.5 L/ha) + Ridomil®WG (2 kg/ha)	40	13	26	53	35	70
10		Foschek® (5 L/ha)	Foschek® (5 L/ha)		49	5	16	44	25	75
11		Curfew® (350 g/ha) + Dithane™ (210 g/ha)	Curfew® (350 g/ha) + Dithane™ (210 g/ha)		47	16	23	46	47	58
12		Captan 600 Flo (4 L/ha)	Captan 600 Flo (4 L/ha)		37	10	20	57	25	77
13		Gem®Fungicide (750 mL/ha)	Gem®Fungicide (750 mL/ha)		45	20	24	50	37	60
14		Sovrin® Flo (360 mL/ha)	Sovrin® Flo (360 mL/ha)		58	18	25	36	35	67
15		FARF2401 Hasten™ (0.5 L/100 L)	FARF2401 Hasten™ (0.5 L/100 L)		37	8	18	56	30	72
16		FARF2402 (149 g/ha)	FARF2402 (149 g/ha)		55	16	26	37	45	57
				Plot value range	**0-100**	**0-80**	**0-100**	**0-100**	**10-80**	**30-90**
				LSD (P≤0.05)	**17**	**8**	**10**	**18**	**9**	**9**
				P value	**P≤0.001**	**P≤0.001**	**P≤0.001**	**P≤0.001**	**P≤0.001**	**P≤0.001**
				CV (%)	**72**	**117**	**85**	**76**	**41**	**20**

* AMISTAR® (a.i. 250 g/L azoxystrobin, Group 11 Fungicide); Captan 600 Flo (a.i. 600 g/L captan, Group M4 Fungicide); Curfew® (a.i. 450 g/kg cymoxanil, Group 27 Fungicide); Dithane™ Rainshield™ Neo Tec™ (a.i. 750 g/ka mancozeb, Group M3 Fungicide); FARF2401 (coded product); FARF2402 (coded product); Foschek® (a.i. 400 g/L phosphorous acid, Group P07 Fungicide); Gem® Fungicide (a.i. 500 g/L fluazinam, Group 29 Fungicide); Opus® (a.i. 125 g/L epoxiconazole, Group 3 Fungicide); Phoenix® Fungicide (a.i. 500 g/L folpet, Group M4 Fungicide); Proline® (a.i. 250 g/L prothioconazole, Group 3 Fungicide); Ridomil® Gold MZ WG (a.i. 40 g/kg metalaxyl-M (mefenoxam) + 640 g/kg mancozeb, Group 4 Fungicide + Group M3 Fungicide); SEGURIS® Flexi (a.i. 125 g/L isopyrazam, Group 7 Fungicide); Sovrin® Flo (a.i. 500 g/L dimethomorph, Group 40 Fungicide).

Note: Treatments 3-16 were applied in addition to standard fungicide programme applied in treatment 2 i.e. 1.5 L/ha Phoenix® applied at 2nd growth regulator timing was also applied with 1 L/ha Opus® and AMISTAR® (0.75 L/ha).

Table 2. Machine dressed seed yield, dressing loss and margin-over-cost (MoC) from cocksfoot (*Dactylis glomerata*) (cv. Savvy) plots treated with 15 different fungicide treatments in a trial conducted near Methven during the 2023-24 season. Cells highlighted yellow show the top statistical group (most effective treatments) based on least significant difference (LSD) (P≤0.05) for each presented variable.

Trt No	Fungicide names**, rates (L/ha) and timing: 2nd Growth Reg (GS 33) (3 Nov 2023)	Ear Emergence (GS 59) (1 Dec 2023)	Flowering (GS 65) (14 Dec 2023)	Flowering + 14 days (GS 71-79) (28 Dec 2024)	Machine dressed seed yield (kg/ha)	Dressing loss (%)	MoC ($/ha)
1	Untreated	-	-	-	911	25	-
2	Opus® (1 L/ha) + AMISTAR® (0.75 L/ha)	Proline® (0.8 L/ha) + SEGURIS®Flexi (0.6 L/ha)	Proline® (0.8 L/ha) + SEGURIS®Flexi (0.6 L/ha)		1260	18	1391
3	Phoenix® (1.5 L/ha)	Phoenix® (1.5 L/ha)			1295	17	1429
4		Phoenix® (1.5 L/ha)	Phoenix® (1.5 L/ha)		1244	19	1161
5	Phoenix® (1.5 L/ha)	Phoenix® (1.5 L/ha)	Phoenix® (1.5 L/ha)		1351	19	1650
6			Phoenix® (1.5 L/ha)	Phoenix® (1.5 L/ha)	1279	19	1346
7		Ridomil®WG (2 kg/ha)	Ridomil®WG (2 kg/ha)		1139	18	546
8		Phoenix® (1.5 L/ha) + Ridomil®WG (2 kg/ha)	Phoenix® (1.5 L/ha) + Ridomil®WG (2 kg/ha)		1362	15	1630
9			Phoenix® (1.5 L/ha) + Ridomil®WG (2 kg/ha)	Phoenix® (1.5 L/ha) + Ridomil®WG (2 kg/ha)	1336	17	1494
10		Foschek® (5 L/ha)	Foschek® (5 L/ha)		1372	16	1800
11		Curfew® (350 g/ha) + Dithane™ (210 g/ha)	Curfew® (350 g/ha) + Dithane™ (210 g/ha)		1242	19	1207
12		Captan 600 Flo (4 L/ha)	Captan 600 Flo (4 L/ha)		1281	18	1283
13		Gem®Fungicide (750 mL/ha)	Gem®Fungicide (750 mL/ha)		1154	18	677
14		Sovrin® Flo (360 mL/ha)	Sovrin® Flo (360 mL/ha)		1201	20	982
15		FARF2401 Hasten™ (0.5 L/100 L)	FARF2401 Hasten™ (0.5 L/100 L)		1188	18	Not Available
16		FARF2402 (149 g/ha)	FARF2402 (149 g/ha)		1238	17	Not Available
				Plot value range	**790-1554**	**11-35**	**-244-2891**
				LSD (P≤0.05)	**167**	**NS**	**NS**
				P value	**P≤0.001**	**0.54**	**0.23**
				CV (%)	**12**	**23**	**64**

NS = No significant difference.
* AMISTAR® (a.i. 250 g/L azoxystrobin, Group 11 Fungicide); Captan 600 Flo (a.i. 600 g/L captan, Group M4 Fungicide); Curfew® (a.i. 450 g/kg cymoxanil, Group 27 Fungicide); Dithane™ Rainshield™ Neo Tec™ (a.i. 750 g/ka mancozeb, Group M3 Fungicide); FARF2401 (coded product); FARF2402 (coded product); Foschek® (a.i. 400 g/L phosphorous acid, Group P07 Fungicide); Gem® Fungicide (a.i. 500 g/L fluazinam, Group 29 Fungicide); Opus® (a.i. 125 g/L epoxiconazole, Group 3 Fungicide); Phoenix® Fungicide (a.i. 500 g/L folpet, Group M4 Fungicide); Proline® (a.i. 250 g/L prothioconazole, Group 3 Fungicide); Ridomil® Gold MZ WG (a.i. 40 g/kg metalaxyl-M (mefenoxam) + 640 g/kg mancozeb, Group 4 Fungicide + Group M3 Fungicide); SEGURIS® Flexi (a.i. 125 g/L isopyrazam, Group 7 Fungicide); Sovrin® Flo (a.i. 500 g/L dimethomorph, Group 40 Fungicide).
Note: Treatments 3-16 were applied in addition to standard fungicide programme applied in treatment 2 i.e. 1.5 L/ha Phoenix® applied at GS 33 was also applied with 1 L/ha Opus® and AMISTAR® (0.75 L/ha).

Appendix Table A1. Cost per hectare per chemical ($/ha Chem), cost per application ($/app), cost per hectare ($/ha) and margin-over-fungicide cost (MoC) for 15 different fungicide treatments applied to control cocksfoot downy mildew in a trial conducted in a cocksfoot seed crop (cv. Savvy) near Methven during the 2023-24 season.

	Fungicide names, rates (L/ha) and timing							
Trt No	**2nd Growth Reg (GS 33) (3 Nov 2023)**	**Ear Emergence (GS 59) (1 Dec 2023)**	**Flowering (GS 65) (14 Dec 2023)**	**Flowering + 14 days (GS 71-79) (28 Dec 2024)**	**$/ha Chem**	**$/app****	**Cost/ha ($/ha)**	**MoC *, *** ($/ha)**
1	Untreated	-	-	-	-	-	-	-
2	Opus® (1 L/ha) + AMISTAR® (0.75 L/ha)	Proline® (0.8 L/ha) + SEGURIS®Flexi (0.6 L/ha)	Proline® (0.8 L/ha) + SEGURIS®Flexi (0.6 L/ha)		352	90	442	1391
3	Phoenix® (1.5 L/ha)	Phoenix® (1.5 L/ha)			89	60	149	1429
4		Phoenix® (1.5 L/ha)	Phoenix® (1.5 L/ha)		89	60	149	1161
5	Phoenix® (1.5 L/ha)	Phoenix® (1.5 L/ha)	Phoenix® (1.5 L/ha)		133	90	223	1650
6			Phoenix® (1.5 L/ha)	Phoenix® (1.5 L/ha)	89	60	149	1346
7		Ridomil®WG (2 kg/ha)	Ridomil®WG (2 kg/ha)		152	60	212	546
8		Phoenix® (1.5 L/ha) + Ridomil®WG (2 kg/ha)	Phoenix® (1.5 L/ha) + Ridomil®WG (2 kg/ha)		240	60	300	1630
9			Phoenix® (1.5 L/ha) + Ridomil®WG (2 kg/ha)	Phoenix® (1.5 L/ha) + Ridomil®WG (2 kg/ha)	240	60	300	1494
10		Foschek® (5 L/ha)	Foschek® (5 L/ha)		123	60	183	1800
11		Curfew® (350 g/ha) + Dithane™ (210 g/ha)	Curfew® (350 g/ha) + Dithane™ (210 g/ha)		30	60	90	1207
12		Captan 600 Flo (4 L/ha)	Captan 600 Flo (4 L/ha)		163	60	223	1283
13		Gem®Fungicide (750 mL/ha)	Gem®Fungicide (750 mL/ha)		100	60	160	677
14		Sovrin® Flo (360 mL/ha)	Sovrin® Flo (360 mL/ha)		42	60	102	982
15		FARF2401 Hasten™ (0.5 L/100 L)	FARF2401 Hasten™ (0.5 L/100 L)		167	60	227	Not Available
16		FARF2402 (149 g/ha)	FARF2402 (149 g/ha)		77	60	137	Not Available
							LSD (P≤0.05)	**NS**
							P value	**0.23**

Note: Treatments 3-16 were applied in addition to standard fungicide programme applied in treatment 2 i.e. 1.5 L/ha Phoenix® applied at GS 33 was also applied with 1 L/ha Opus® and AMISTAR® (0.75 L/ha).

* MoC for treatments were calculated based on product price per litre or gram with treatments 3-16 including the cost the standard fungicide programme applied in treatment 2 based on: AMISTAR® (a.i. 250 g/L azoxystrobin, Group 11 Fungicide, $49.7/L); Captan 600 Flo (a.i. 600 g/L captan, Group M4 Fungicide, $20.3/L); Curfew® (a.i. 450 g/kg cymoxanil, Group 27 Fungicide, $0.031/g); Dithane™ Rainshield™ Neo Tec™ (a.i. 750 g/ka mancozeb, Group M3 Fungicide, $0.018/g); FARF2401 (coded product, price not available); FARF2402 (coded product, price not available); Foschek® (a.i. 400 g/L phosphorous acid, Group P07 Fungicide, $12.3/L); Gem® Fungicide (a.i. 500 g/L fluazinam, Group 29 Fungicide, $66.5/L); Opus® (a.i. 125 g/L epoxiconazole, Group 3 Fungicide, $35.3/L); Phoenix® Fungicide (a.i. 500 g/L folpet, Group M4 Fungicide, $29.5/L); Proline® (a.i. 250 g/L prothioconazole, Group 3 Fungicide, $84.9/L); Ridomil® Gold MZ WG (a.i. 40 g/kg metalaxyl-M (mefenoxam) + 640 g/kg mancozeb, Group 4 Fungicide + Group M3 Fungicide, $0.037/g); SEGURIS® Flexi (a.i. 125 g/L isopyrazam, Group 7 Fungicide, $119.5/L); Sovrin® Flo (a.i. 500 g/L dimethomorph, Group 40 Fungicide, $58.7/L).

** Price per application is based on standard FAR operating costs.

*** MoC, margin-over-fungicide cost was calculated based on average cocksfoot seed price at harvest of $5.25 per kg (effective May 2024).

Summary
Downy mildew pressure in this trial was moderate compared to higher levels observed in the 2021-22 season and lower levels in 2022-23. This variability was influenced by wet, cool conditions during early crop development, which favoured disease onset, followed by dry, hot weather later in the season that reduced infection risk. Fungicide treatments showed varying efficacy, with Phoenix® (folpet, Group M4) and Foschek® (phosphorous acid, Group P07) reducing disease symptoms and seed head bleaching, while treatments like Ridomil® Gold MZ WG, Gem® and Curfew® were less effective. Economic analysis revealed no significant differences in margin-over-cost (MoC) among treatments. These findings underscore the need for targeted fungicide selection and precise application timing to manage cocksfoot downy mildew efficiently.

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