Perception vs practice: Farmer attitudes towards and uptake of IPM in Scottish spring barley

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Abstract: Integrated Pest Management (IPM) offers a suite of ways by which to reduce the need for pesticide use, thus minimising environmental damage and pathogen resistance build-up in crop production. Farmers and agronomists active in the Scottish spring barley sector were surveyed to determine the extent to which they currently use or are open to implementing three IPM measures - varietal disease resistance, crop rotation, and forecasting disease pressure - in order to control three important fungal diseases. Overall, the survey results demonstrate that farmers and agronomists are open to using the three IPM techniques. However, gaps between actual and perceived recent practice were large: despite over 60% of farmers stating that they sowed varieties highly resistant to Rhynchosporium or Ramularia, less than one third of reportedly sown varieties were highly resistant to these diseases. Similarly, over 80% of farmers indicated that they used crop rotations, yet 66% of farmers also reported sowing consecutive barley often/always. Further research is needed in order to understand why these gaps exist, and how they can be reduced in future in order to increase IPM uptake and optimise pesticide use.

Dear Editor,

I am writing to submit "Perception vs practice: farmer attitudes towards and uptake of IPM in Scottish spring barley" for the consideration of Crop Protection.

This study assessed current practice and perceptions of three IPM techniques of relevance in the Scottish spring barley sector, in relation to three key diseases – Rhynchosporium, Mildew, and Ramularia. The aim was to understand whether farmers and agronomists were already using crop rotation, varietal disease resistance, or forecasting disease pressure to manage these diseases, and, if not, to what extent they would be open to taking these up in future.

The survey results indicate that the stakeholders studied are open to taking up all three IPM techniques. However, gaps between actual and perceived recent practice were large: despite over 60% of farmers stating that they sowed varieties highly resistant to Rhynchosporium or Ramularia, less than one third of reportedly sown varieties were highly resistant to these diseases. Similarly, over 80% of farmers indicated that they used crop rotations, yet 66% of farmers also reported sowing consecutive barley often/always.

Such a gap between perception and practice does not appear to have been previously reported in IPM, and the reasons behind it are not currently known, though it may have important consequences in terms of pest management strategies. If farmers and agronomists believe themselves to already be making use of IPM techniques to their fullest, and seeing no reduction in disease severity, this could prove a barrier to encouraging further uptake of IPM, regardless of the scientifically proven benefits of such systems. These results are particularly timely due to the incorporation of IPM into the recent EU CAP reform, and may explain some of the lack of IPM uptake in the past.

I believe this work would fit with the aim of Crop Protection to publish interdisciplinary work around control strategies, particularly as understanding the practical reasons for a lack of uptake of IPM is crucial for improving uptake of such strategies in future.

This manuscript has not previously been published in any language, and is not under consideration for publication in any other journal. The manuscript has also been approved by all co-authors listed for submission to Crop Protection.

Sincerely,

Stacia Stetkiewicz

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Highlights

- Farmers and agronomists were open to using IPM in Scottish spring barley production
- Gaps between actual and perceived practice were large
- While more than 60% of farmers stated that they sowed spring barley varieties which were highly resistant to Rhynchosporium or Ramularia often/always, less than one-third of reportedly sown varieties were highly resistant to these diseases
- Over 80% of farmers indicated that they used crop rotations, yet 66% of farmers also reported sowing consecutive barley often/always

Perception vs practice: farmer attitudes towards and uptake of IPM in Scottish spring barley

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Keywords: Integrated Pest Management, Farmer decision making, Disease resistance, Crop rotation

1.1 Abstract

Integrated Pest Management (IPM) offers a suite of ways by which to reduce the need for pesticide use, thus minimising environmental damage and pathogen resistance build-up in crop production. Farmers and agronomists active in the Scottish spring barley sector were surveyed to determine the extent to which they currently use or are open to implementing three IPM measures – varietal disease resistance, crop rotation, and forecasting disease pressure – in order to control three important fungal diseases. Overall, the survey results demonstrate that farmers and agronomists are open to using the three IPM techniques. However, gaps between actual and perceived recent practice were large: despite over 60% of farmers stating that they sowed varieties highly resistant to Rhynchosporium or Ramularia, less than one third of reportedly sown varieties were highly resistant to these diseases. Similarly, over 80% of farmers indicated that they used crop rotations, yet 66% of farmers also reported sowing consecutive barley often/always. Further research is needed in order to understand why these gaps exist, and how they can be reduced in future in order to increase IPM uptake and optimise pesticide use.

1.2 Introduction

A key challenge facing the present day agricultural sector is the maintenance of high yields while minimising environmentally damaging practices, in order to balance the short- and long-term needs of global food security. One way of attempting to achieve this balance is through the better management of inputs in conventional agriculture, ensuring that

products such as pesticides are used only when needed. Pesticide use is widespread, in the aim of maintaining yields (Cooper & Dobson, 2007), but with a variety of concurrent detrimental effects, such as non-target organism toxicity (Beketov et al., 2013), reduced soil biodiversity and health (Walia et al., 2014), and threats to human health (Weisenburger, 1993). Additionally, overuse of, and overreliance upon, pesticides can lead to pests and pathogens developing resistance to active ingredients, thereby reducing their efficacy (Birch et al., 2011; Fungicide Resistance Action Committee, 2012). The Scottish Government (2016) recommends the use of Integrated Pest Management (IPM), to combat the development of disease resistance, reduce risks to human health, and provide environmental benefits.

IPM is an ecosystem approach which encompasses a variety of techniques for management of pests and diseases, used in combination, and aiming to decrease pesticide use (FAO, 2016). Pesticide use is not prohibited under IPM; rather, the aim is to reduce the need for pesticides, by minimising the likelihood of an epidemic. IPM was first conceptualised over 50 years ago (Stern et al., 1959), yet little is known about its adoption, the barriers to its uptake, and how it is perceived by farmers. In recent years, several surveys of farmers have been carried out in order to gain understanding of IPM-related attitudes, uptake, and priorities – some of these provide case-studies of specific systems (Ilbery et al., 2012; Sherman & Gent, 2014), while others consider a broader range of systems and questions (ADAS, 2002; Bailey et al., 2009; Lamine, 2011). Despite a growing body of literature, relatively little is known about farmer attitudes towards IPM, still less that is relevant in the context of Scottish spring barley (the principle arable crop in Scotland). Information on this topic could aid in focusing research and policy decisions. A number of key legislation changes have also occurred in recent years, including the EU Sustainable Use Directive, which requires member states to support the uptake of IPM (DEFRA, 2013). In light of these policy changes, considering the issues surrounding uptake and interest is a useful exercise.

As the uptake of and attitudes towards IPM are intertwined with market forces and product availability, surveying stakeholders may provide insight into the complex realities which influence IPM decisions. This survey builds on previous work which analysed risk, attitudes towards innovation, and sources of information relating to IPM in the UK (Bailey et al., 2009; ADAS, 2002; Ilbery et al., 2013), with a focus on three key fungal diseases

affecting spring barley in Scotland – Mildew (caused by *Blumeria graminis f. sp. hordei*), Rhynchosporium (caused by *Rhynchosporium commune*), and Ramularia (caused by *Ramularia collo-cygni*). These are the three most commonly targeted diseases by Scottish farmers when applying fungicides to spring barley (Scottish Government, 2014). Yield reductions due to mildew have been recorded in the range of 11 – 17% for susceptible varieties (Lim & Gaunt, 1986; Hysing et al., 2012); reductions of 30 – 40% due to Rhynchosporium (Shipton et al., 1974, cited in Zhan et al., 2008); and Ramularia losses in the UK have been noted at 7 – 13% (Oxley et al., 2008), though reductions of up to 70% have been reported due to severe epidemics in South America (Pereyra 2013 cited in Havis et al., 2015). A case-study approach was taken, analysing farmer and agronomist perceptions of three IPM strategies in relation to key fungal diseases of spring barley, providing a snapshot of current barriers and attitudes.

1.2.1 Survey Aims

The primary goal of this survey was to understand the extent to which farmers would be open to implementing, or had already made use of, three IPM strategies identified as having the potential to reduce the need for fungicide use in the cultivation of Scottish spring barley, namely: planned crop rotation, varietal disease resistance, and forecasting disease pressure. Results from the latter IPM technique are not discussed in detail this paper, as sufficient data to compare actual and perceived uptake of forecasting were not gathered in this survey. The primary target population identified was Scottish spring barley farmers, with a secondary target population of agronomists involved in the production of Scottish spring barley, of which a convenience sample (a non-random sample of individuals who are selected based on ease of sampling) was taken in order to obtain a large number of responses despite limited resources. Surveying both farmers and agronomists also allowed for a direct comparison of their opinions and perceptions, providing insight into persistent patterns between the two groups.

1.3 Methods

1.3.1 Designing the survey

The survey was designed to be run at the annual agronomy events co-hosted by Scotland's Rural College (SRUC) and Agriculture and Horticulture Development Board (AHDB):

Cereals and Oilseeds, where a series of presentations by experts were given around the theme of risk, resilience, and reward at Carfraemill (Scottish Borders), Perth (Tayside), Inverurie (North East), and Inverness (Highlands) during January 2016. These four sites represent a useful geographical spread for data collection, as they are distributed across the main cereal production areas in Scotland. Different farm structure, as assessed at regional level, is also captured by this sample; for example, the Tayside and Scottish Borders regions have more large holdings (>200ha) than average, while Highland has fewer than average (Scottish Government, 2015). A total of 288 surveys were given out across the four locations (Carfraemill – 100; Perth – 81; Inverurie – 71; Inverness – 36). The survey comprised six sections, where farmers were asked about a range of issues relating to IPM, as well as demographic details. Farmers were asked how often they sowed varieties which were highly resistant to each disease, and to list the varieties they had sown in the past five years, alongside how often they sowed consecutive barley/cereals. Questions were also included relating to attitudes towards fungicide use, and the perceived impact of fungicide use on spring barley yields. Best-worst scaling questions were included to assess which IPM techniques farmers would be most/least open to taking up and which were most/least practical overall and in terms of cost.

To obtain the most relevant information possible, participants were instructed to respond about their majority practices in the survey, recognising that there may be variation at field level within the farm. All farmers at the events who grew spring barley in some capacity were invited to participate, as were agronomists who were involved in decision making for spring barley. The appropriate ethical guidelines were followed for the University of Edinburgh, SRUC, and Scottish Government. The questionnaire went through a number of iterations with feedback given first by a pre-pilot group of seven PhD students, then by a pilot group of four farmers and five agronomists. Pilot participants were asked to give general feedback about the wording of questions and their answers, as well as specific feedback for key questions highlighted in the pre-pilot study and follow-on discussions.

1.3.2 Analysis

Final results from the questionnaire were first analysed for sampling bias. Consistency across sites was verified for demographic questions (e.g. age and education), as well as one

question chosen at random from each survey section. A summary of the sample population was then developed, and compared with the target population statistics available from the Scottish Government. Finally, to verify a lack of attendance bias between sites, several key questions were summarised based on location of survey completion and compared. For questions relating to varietal resistance, comparisons were made using the SRUC/SAC Cereal Recommended Lists for the relevant year (2011; 2012; 2013; 2014). Due to the small sample size and the use of a non-random sampling method, statistical analysis of survey results is presented only where the sample size is thirty or above.

The likelihood of obtaining varietal disease resistance at the levels reported by farmers and agronomists by random chance was also assessed. The average disease resistance rating for each disease was calculated based on the malting varieties reported as having been sown by farmers, and, separately, agronomists. Simulated disease resistance values were then created, by randomly selecting malting varieties for 2011 - 2014, creating a sample equal to the number of farmers/agronomists who answered these questions in the survey. A mean value of these simulated results was then taken for each disease resistance. This process was repeated 100 times, to create a simulated distribution of the disease resistance ratings which would be expected by random chance. This was then compared against the actual disease resistance ratings reported by farmers and agronomists, to determine the probability of obtaining resistance ratings at least as high as what was reported by stakeholders by chance. This process was then repeated, using only varieties with a disease resistance rating of seven or more (or, in cases where no malting varieties had a rating of seven or more for a given disease/year combination, the highest possible rating was chosen instead), to determine the probability of obtaining varietal disease resistance ratings as low as what was reported by stakeholders, if they were selecting varieties from the most highly resistant choices available in each year.

Chi-square tests were then used to compare results from agronomists and farmers, to determine whether there were significant differences between their reported sowing of consecutive barley/cereals, and beliefs in relation to fungicide use (e.g. "I think finding methods to reduce fungicide use is important") and fungicide impact on yield.

1.4 Results

1.4.1 Survey demographic

A total of 43 farmers and 36 agronomists responded to the survey, giving an overall response rate of 27% (Carfraemill – 15%; Perth – 31%; Inverurie – 30%; Inverness – 44%). Farmers surveyed presented a young, highly educated population with slightly larger farms than average (Scottish Government, 2015). The spring barley producing regions of Scotland were well represented in the survey, with only two of the national sub-regions having a discrepancy of over 10% between the survey population and the Economic Report on Scottish Agriculture 2015 percentage of surveyed farms in each region: overrepresentation of the Highlands (15% difference); and underrepresentation of Tayside (18% difference). Distilling was the main spring barley market for more than three quarters of the surveyed farmers. A large proportion (45.24%) of the farmers were affiliated with an environmental scheme or programme, as compared to the 28% of Scottish agricultural land reported to be under an agri-environmental scheme in 2014 (Defra, 2015). The regions in which agronomists advised farmers were similar to those represented in the farmer survey, and all agronomists indicated that they were experts in relation to spring barley. More than half of the agronomists surveyed (55.6%) were affiliated with trade/distribution.

1.4.2 Disease perception and varietal choice

Farmer survey – disease perception

Most farmers (94.6%) believed that foliar diseases of spring barley were important or very important in determining yield, with Rhynchosporium indicated by the majority as being the most common of the three pathogens on spring barley in the past five years, as well as having had the greatest impact on yield.

Farmer survey - varieties

Farmers were asked to list the top three varieties of spring barley they had sown in the past five years – the large majority of these, for which information is available in the 2011 – 2015 SRUC Cereal Recommended Lists, were distilling varieties. Over 60% of farmers stated that the varieties they sow are often or always highly resistant (a rating of 7 or more on the Recommended List was specified as being 'highly resistant' in the survey) to each of the three diseases in question. However, while 84.6% of varieties sown by farmers were highly

resistant to Mildew, for Ramularia only 27.3% were highly resistant, and for Rhynchosporium 23.1%. In most years the majority of varieties cultivated had lower disease resistance ratings than the 'best available choice' – that is, the distilling variety with the highest average disease resistance rating in that year (see Table 1). Over 75% of the varieties listed by farmers who stated that they always/often sow highly resistant varieties to mildew were, in fact, highly resistant to mildew – by contrast, for Rhynchosporium and Ramularia, less than 25% of these were highly resistant according to the Recommended Lists. Farmers who stated a given disease is the most common/impacts yield most did not sow a higher proportion of varieties which were highly resistant to that disease for Mildew or Ramularia, however, where farmers thought Rhynchosporium impacted yield most, a higher proportion of varieties they sowed were highly resistant. Despite farmer self-reporting that they often/always sow highly resistant varieties for all three diseases, then, this was not actual practice for Rhynchosporium in 2011-15 or Ramularia in 2012 – 15 (Ramularia was not included in the Recommended List resistance ratings prior to 2012, so published information is not available for comparison in 2011).

Simulated random varietal disease resistance comparisons showed that the probability of getting resistance ratings at least as high as the average ratings of varieties sown by farmers/suggested by agronomists by random chance was high (see Table 2). The probability of obtaining resistance ratings at least as low as those sown by farmers/suggested by agronomists by random chance, if the stakeholders were choosing from the highly resistant malting varieties available in a given year, was less than 0.01 in all cases (see Table 3).

Table 1: Disease resistance of the varieties sown by surveyed farmers

Year	Disease	Percent of varieties listed which were highly resistant to this disease	Percent of varieties listed which were below the best possible choice	Average varietal resistance rating for this disease	Standard error of mean varietal resistance rating
2015	Mildew	88%	20%	8.5	0.14
	Rhynchosporium	0%*	70%	4.6	0.12
	Ramularia	15%	13%	6.1	0.13
2014	Mildew	90%	68%	8.0	0.15
	Rhynchosporium	31%	69%	5.7	0.19
	Ramularia	22%	78%	6.1	0.07
2013	Mildew	90%	75%	8.0	0.15
	Rhynchosporium	23%	77%	4.6	0.20
	Ramularia	23%	77%	6.1	0.08
2012	Mildew	76%	76%	7.5	0.02
	Rhynchosporium	18%	90%	4.6	0.22
	Ramularia	9%	5%	6.0	0.06
2011	Mildew	70%	78%	7.3	0.25
	Rhynchosporium	28%	100%	4.8	0.23

* No fully approved malting varieties on the Scottish Recommended List were highly resistant to Rhynchosporium in 2015

Table 2: Comparison of randomly simulated disease resistance ratings with ratings of sown/recommended varieties

	Mildew	**Rhynchosporium**	**Ramularia**
Average resistance rating of varieties sown by farmers	7.8	5.0	5.9
Probability of getting resistance ratings at least this high by random chance	0.1	0.99	0.55
Average resistance rating of varieties suggested by agronomists	7.8	4.9	5.9
Probability of getting resistance ratings at least this high by random chance	0.1	1.0	0.55

Table 3: Comparison of randomly simulated highly disease resistant ratings with ratings of sown/recommended varieties

	Mildew	Rhynchosporium	Ramularia
Average resistance rating of varieties sown by farmers	7.8	5.0	5.9
Probability of getting resistance ratings at least this low by random chance, if farmers were selecting highly resistant varieties	<0.01	<0.01	<0.01
Average resistance rating of varieties suggested by agronomists	7.8	4.9	5.9
Probability of getting resistance ratings at least this low by random chance, if agronomists were selecting highly resistant varieties	<0.01	<0.01	<0.01

Agronomist survey

The varieties recommended by agronomists and those listed by farmers were broadly similar, with four of the five most commonly recommended also being the most commonly sown. The pattern of disease resistance for varieties recommended by agronomists was similar to that of the varieties sown by farmers – despite a majority of agronomists stating that they always/often recommended highly resistant varieties for each disease, most varieties listed were highly resistant to Mildew (84.6%) in clear contrast to Ramularia (11.1%) and Rhynchosporium (30.8%).

1.4.3 **Use of rotations**

Farmer survey

All but five of the surveyed farmers stated that they used rotations, and the factor which ranked most highly in terms of influencing the decision to use this rotation was 'to spread risk of low yields/crop failure' (average rank of 1.77, standard error: 0.19) with disease reduction being second (average rank of 2.375, standard error: 0.13). Of the five farmers not using rotations, the need to fulfil contracts for their main crop, and thus the need to sow large amounts of land to a single crop was the mostly highly ranked factor influencing their lack of rotation use. However, the majority of farmers often or always sow barley and/or

cereals consecutively – 66.67% and 82%, respectively (see Figure 1). Farmers who chose disease reduction as one of their top two reasons for using a rotation were more likely to rarely/never sow consecutive barley/cereals than their counterparts, but consecutive sowing remained the norm in this group.

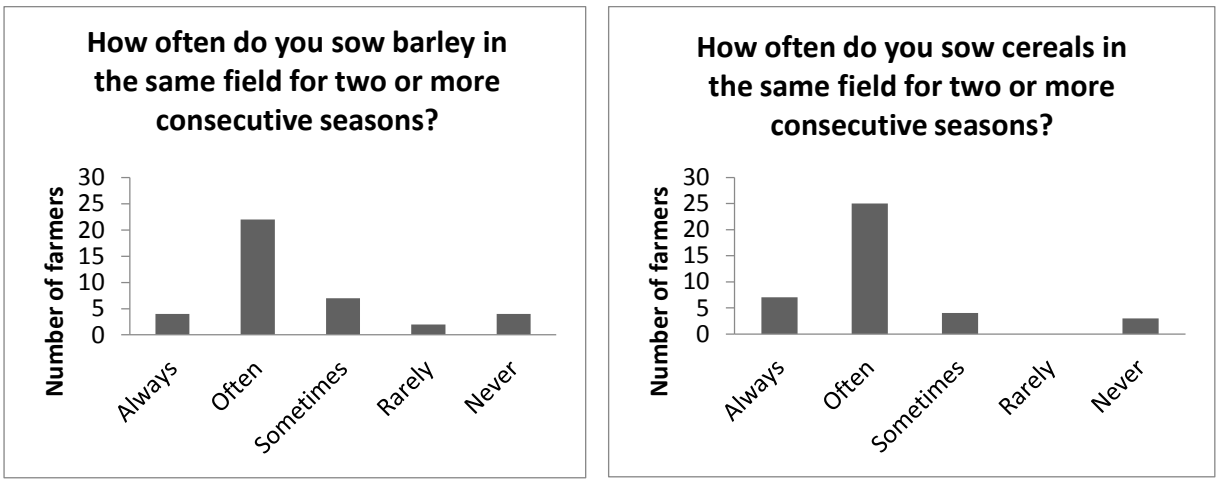

Figure 1: Self-reported frequency of use of consecutive barley or cereals

Agronomist survey

When recommending a rotation, the highest ranked factor involved in the decision was to reduce fungal disease, while the highest ranked factor when agronomists did not recommend a rotation was the need to fulfil contracts for the main crop. A majority of agronomists (60.6%) often/always recommended sowing consecutive cereals. Recommending sowing consecutive barley was less common, with just under half of the agronomists (48.5%) suggesting this often/always.

Chi-square comparison

There was no significant difference ($p = 0.1366$) between the proportion of farmers who always/often sow barley in the same field for two or more consecutive seasons and the proportion of agronomists who recommend doing this. However, there was a significant difference ($p = 0.0486$) between the proportion of farmers who always/often sow cereals in the same field for two or more consecutive seasons and the proportion of agronomists who recommend doing this – 60.6% of agronomists recommended doing this, while 82.3% of farmers did this always/often.

1.4.4 Fungicide use

Farmer and agronomist survey

Fungicide use was widespread amongst the surveyed farmers, with 37 of 39 applying fungicides to their spring barley crop every year. The impact of fungicide use on spring barley yields was thought to be an increase of 1-2 tonnes per hectare by most farmers (72%) and agronomists (75%) (see Table 4). There was no significant difference ($p = 0.7374$) between the proportion of farmers versus agronomists who believe the yield increase due to fungicide application is greater than 1 t/ha, as assessed by a chi-square test. Given the average estimated yield of spring barley in Scotland of 5.7t/ha, based on data from 2010 – 2014 (Scottish Government, 2015), farmers and agronomists therefore perceive a yield benefit of between 17.5 – 35% from fungicide use. The majority of agronomists recommended fungicide use to farmers for foliar diseases in spring barley every year to every client.

Table 4: Farmer and Agronomist estimation of the increase in spring barley yields due to fungicide use

How much (in t/ha) do you think fungicide use increases spring barley yields by?

	Number of farmers	Percent of farmers	Number of agronomists	Percent of agronomists
Less than one tonne per hectare	5	12.8%	5	15.6%
1 - 2 tonnes per hectare	28	71.8%	24	75.0%
2 - 3 tonnes per hectare	5	12.8%	2	6.3%
3 - 4 tonnes per hectare	1	2.6%	1	3.1%
More than 4 tonnes per hectare	0	0.0%	0	0.0%

1.4.5 Perceptions of IPM strategies and fungicides

Farmer survey

More than 80% of farmers were open to reducing their fungicide use if they could achieve the same yields and/or have fungicide reduction be cost-effective. A majority were also concerned about fungicide resistance, the amount of fungicides that they themselves use, and felt that finding methods to reduce fungicide use is important (see Figure 2).

Chi-square tests found no significant difference between farmer and agronomist beliefs in relation to fungicide use for the statements: "I think fungicide use can negatively impact the

environment" ($p = 0.1141$); "If I could use less fungicide and achieve the same yields, I would"/ "If using less fungicide could achieve the same yields, I would recommend using less fungicide to farmers" ($p = 0.5872$); "I have no concerns about the amount of fungicide I use on my spring barley"/ "I have no concerns about the amount of fungicides farmers use on spring barley" ($p = 0.2293$); "If I could use less fungicide and have it be as cost-effective, I would"/ "If using less fungicide was as cost-effective, I would recommend using less fungicide to farmers" ($p = 0.5820$); "I think finding methods to reduce fungicide use is important" ($p = 0.8445$); "I am not concerned about fungicide use leading to fungicide resistance" ($p = 0.0558$).

A series of best-worst scaling questions asked farmers first about the perceived practicality and second the perceived practicality in terms of cost of implementation of each IPM technique. For both of these questions some farmers chose each technique as most/least practical, with sowing only disease resistant varieties being most popular overall – this is shown in the bubble plot in Figure 3, which represents the combinations of choices made by farmers. The overall most preferred selections are in the top right hand corner of the graph – e.g. where a farmer has chosen a given technique as best both in terms of practicality and cost-effectiveness. As bubble size indicates the number of times a given combination was chosen, the outer colour of the bubble indicates the IPM technique which was most frequently chosen for this combination. Sowing only disease resistant varieties was most frequently chosen as the 'best' technique, both in terms of practicality and cost, though all three techniques were identified as both 'best' and 'worst' by some farmers. All three techniques are therefore suitable for some of the survey population, and not for others – none are universally unacceptable.

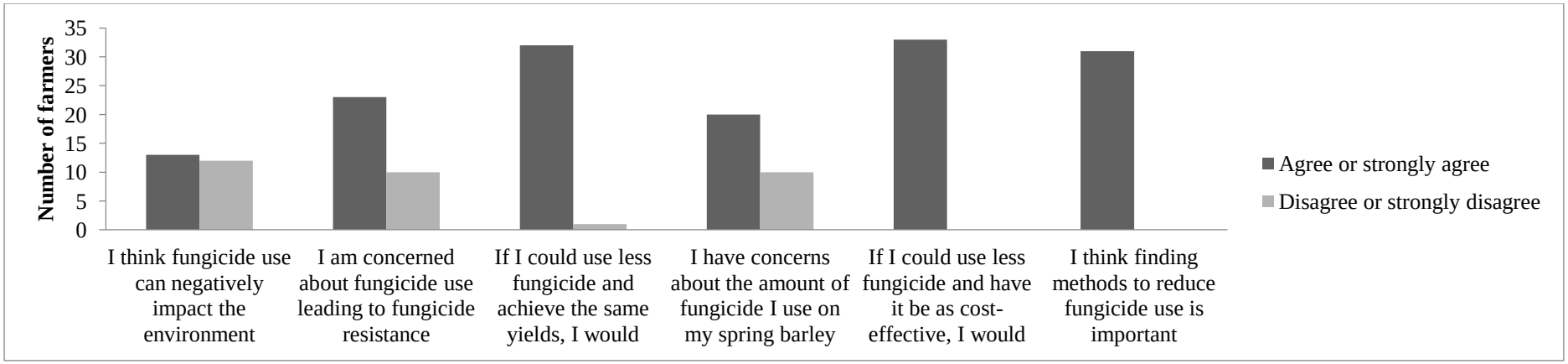

Figure 2: Summary of farmer's polarised attitudes towards fungicide use

Figure 3: Best-Worst Scaling bubble plot of farmer perceptions of IPM techniques in terms of cost and practicality of implementation

Agronomist survey

A majority of agronomists strongly agreed or agreed that if using less fungicides could achieve the same yields or be as cost-effective, they would recommend using less fungicide, were concerned about fungicide resistance and felt finding methods to reduce fungicide use was important. Each IPM technique was chosen as best/worst by at least one agronomist in terms of practicality and cost. All three IPM techniques were already being recommended by agronomists.

1.5 Discussion

Farmer's reactions towards the IPM practices presented were generally positive, with some farmers willing to take up each measure. However, a contradiction between farmer perception of their own IPM uptake and their self-reported practices was noticeable, in regards to both varietal disease resistance and rotation use. Farmer openness to IPM and lack of uptake – as evidenced by low proportions of varieties being highly resistant to key diseases, and high proportions of farmers sowing consecutive barley – provide a clear suggestion that IPM application can be improved in Scottish spring barley production. The results presented here should be interpreted with caution due to the relatively small sample size of 43 farmers, as well as the bias potentially introduced through the sampling strategy.

1.5.1 Bias potentially introduced by Agronomy events

The similarity in topic between the survey and the focus of the events (Risk, Resilience, and Reward) presented both an opportunity to increase participation and an area of potential bias. A number of presentations specifically mentioned IPM, and discussed fungicide use on cereals, thus priming participants to consider these issues, possibly prior to completing the survey. Participants may have been influenced in particular by "Disease and fungicides: Lessons from 2015, messages for 2016," a presentation in which were discussed trial results from SRUC work during the past year regarding key fungicides for spring barley, oilseed rape, and wheat. In order to reduce bias, no results were presented which specifically stated the impact of fungicide use on yields of spring barley. Although this information was presented for both oilseed rape and wheat trials, the potential for generating bias may have been mitigated to some extent by the fact that the impacts of fungicide presented for these two crops were dissimilar (1.97 t/ha for wheat vs 0.58 t/ha for oilseed rape). An upper and

lower conceptual limit of the extent to which fungicide use can impact yield may have been suggested by this presentation, however, of approximately two tonnes and a half tonne per hectare respectively.

While measures were taken to reduce the direct influence of the events on survey results, the self-selection bias which is inherent in all voluntary surveys will here be magnified by the initial self-selection of attendance at events relating to disease management. While not all presentations focused on IPM, and some farmers may have attended solely to discover which fungicides would be best suited to their crops in 2016, the impact of the numerous mentions of IPM on participant mentality while completing the survey must be recognised. Survey results should therefore be interpreted in this light – farmers represented not only an early adopter of innovation group, based on age, farm size, and education characteristics (Diederen et al., 2003; Rogers, 1961), but also a group which was primed to consider IPM in a positive light. The survey results should be seen as a best case scenario, from the perspective of openness to IPM.

1.5.2 Farmer attitudes towards IPM

That farmers had concerns about fungicide use leading to resistance was evident, as was their willingness to reduce fungicide use if this could be cost-effective. Interest in using the three IPM strategies presented was more variable within the group. All three strategies received some positive and some negative responses, with no single technique being preferred by a large majority of farmers. Agronomist responses were similarly open, with each technique being chosen as 'best' by some participants and 'worst' as others, with the use of highly resistant varieties being most commonly preferred. Farmer and agronomist attitudes towards fungicide use were remarkably similar, with no significant differences found between fungicide perception statement agreements between the two groups.

1.5.3 Discrepancies between perception and practice

In spite of this generally positive attitude towards IPM, a clear mismatch was seen between perceptions/intent and actual practice for both IPM techniques investigated in detail in the survey – varietal disease resistance and rotation – as well as the impact of fungicide use on yield. First, a disparity was seen between farmer perceptions of their use of highly resistant varieties and the reality of varietal disease resistance, based on their own lists of varieties

sown in the past five years. While the majority of farmers stated that they sowed highly resistant varieties to all three diseases, disease resistance ratings for the varieties listed by farmers for Ramularia and Rhynchosporium contradicted this. In addition, simulations of disease resistance found the likelihood of sowing varieties with resistance ratings as high as farmers reported was not significantly different to those produced by random chance, highlighting the lack of use of varietal disease resistance when choosing varieties. Further, the disease resistance ratings of the varieties sown by farmers were significantly lower than those which would be expected if farmers were selecting from within the choice of highly resistant varieties in a given year. Differences between perceived and actual behaviour have long been studied in the field of psychology, and recent work, (e.g. Niles, Brown and Dynes, 2016) has expanded this to include studies of farmers and climate change, showing that intended and actual adoption of climate change mitigating management strategies were dissimilar. To the best of our knowledge, the contradiction between practice and perception has not, however, been reported in the context of IPM uptake before.

That this gap was mirrored in the agronomist survey highlights how widespread the pattern is, and may, in fact, perpetuate the discrepancy. Recent work on relationships between farmers and agronomists has shown that, though there are a number of agronomist-farmer relationship types, agronomists are frequently seen as experts whose advice is crucial in decision making (Ingram, 2008; Sherman & Gent, 2014). A similar gap was seen in relation to rotation use in the survey. Nearly all farmers surveyed stated that they used rotations, with disease reduction being the second most highly ranked reason for using a rotation, after spreading risk. Due to the nature of a rotation, it is not possible from the data collected to be certain which crop disease(s) farmers are primarily using rotations in order to manage. The fact that the majority of farmers are often/always sowing both consecutive barley and cereals, despite disease reduction being a highly ranked reason for using rotation is, however, concerning, as consecutive sowing may undermine any disease reduction objectives farmers have, by maintaining inoculum sources across years. While there was no significant difference between the number of farmers who sowed barley consecutively and the number of agronomists who recommended doing this, there were significantly fewer agronomists who reported recommending sowing consecutive cereals than farmers who did this. The reasons for this difference are unknown. However, as a majority of agronomists

still did recommend sowing consecutive cereals (60.6%) often/always to their clients, this figure still represents a substantial lack of uptake of IPM.

Previous work on spring barley production in England found yield increases of 2.4 – 13.8% due to fungicide use (Priestley and Bayles, 1982), suggesting farmer and agronomist perception of fungicide use as increasing yields by 17 – 35% may be an overestimation. However, more recent field trial information is needed to make a full comparison, in order to account for changes in chemistry and cultivars.

These disparities between perception and reality have concerning implications for the uptake of IPM techniques. If farmers and agronomists believe themselves to be using IPM to its fullest, e.g. sowing highly resistant varieties and using crop rotations, they may be more likely to dismiss these as options for further reducing disease burden. Further, farmer surveys should be cautious when interpreting self-reported farmer information, as answers to indirect questions (e.g. 'How often do you use crop rotations' vs 'How often do you sow consecutive barley') may be misleading.

Market forces, which have long been recognised as a key driver in the complexities of farm risk and innovation (Ghadim & Pannell, 1999; Marra et al., 2003; Hughes et al., 1999), are likely to be influencing farmer uptake of IPM methods, as varietal choice is restricted to the varieties preferred by the market, and rotation plans may change in response to grain prices. That varietal choice is not simply a matter of resistance rating versus potential yield is clear, as illustrated by the varieties sown by surveyed farmers in 2015: 55% of farmers sowed Concerto, while 10% chose Odyssey. Both varieties had full brewing and distilling approval, and the same disease ratings for Mildew and Ramularia; Odyssey had a Rhynchosporium rating of 6, while Concerto had a rating of 4. The estimated yield for Odyssey was also higher, at 6.94 t/ha versus 6.53 t/ha for Concerto. By these metrics, then, Odyssey is the variety which would be expected to be widespread. That the reality is the inverse suggests other factors are at play, such as barley contracts which specify the variety to be produced, seed availability, or farmer preference for other varietal characteristics. Resistance rating may therefore be used in decision making as a 'deal breaker' when choosing between two or more varieties of equal market value, rather than vice versa.

Other IPM techniques may be seen in a similar manner – for example, farmers may generally use crop rotations, but alter this when market prices indicate it would be beneficial to do so. Clearly, this approach makes financial sense in the short-term, however as benefits from IPM are cumulative, breaks in IPM use reduce efficacy in the long-term. This, in turn, may cause stakeholders to question their effectiveness, and thus break the cycle again. It is crucial for farmers to both understand their actual practice on farm to ensure IPM perceptions are based on reality, as well as to be willing to continue using IPM in a longer term context in order to see full the full benefits.

1.6 Conclusions

Farmer attitudes towards the IPM measures of interest were broadly positive – each technique was thought to be most practical and cost effective by some farmers, and can therefore be posited as feasible options in relation to IPM uptake in Scottish spring barley. However, the two IPM techniques which were investigated in further detail – planned crop rotation and sowing disease resistant varieties – showed a substantial gap between farmer perception and practice, such that where these techniques were being used by farmers they were not fully optimised. This has implications for overall uptake of IPM measures. If farmers believe themselves to be using an IPM technique to its fullest and yet not reaping any benefits, this could cause drop off in usage and/or dissuade them from taking up new IPM measures. The reasons behind this gap are not fully understood, but could include lack of trust in official sources of information (e.g. Cereal Recommended Lists) or an inaccurate reflection of practices on farm in the survey results, for example due to poor memory of varieties sown. There may be a need for more targeted information transfer between scientists and farmers, as has been recommended for integrated weed management (Wilson et al., 2009), in order to improve knowledge about disease resistance and rotations. Further research into gaps between perceived and actual practice could deepen understanding of this phenomenon and help to produce relevant policy and scientific recommendations.

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Supplementary materials: farmer and agronomist questionnaire

What are your experiences of foliar diseases and their management in spring barley?

THIS SURVEY SHOULD ONLY TAKE 10 MINUTES

This survey forms part of a project on diseases in spring barley in Scotland. Its goals are: to pinpoint the factors which influence yield; to understand what types of management practices are already widely used in Scotland; and identify those which may be useful in future. Your insights and practical experience are vital to this process, and will help to ensure that our results are relevant and useful for Scottish farmers.

By completing this survey you are agreeing to have your results analysed as part of this project. Individual responses will be kept anonymous and will be used by the SRUC to better understand Integrated Pest Management in Scotland's barley fields, develop suggestions for future techniques which will best suit Scottish agriculture, and to complete my PhD thesis. They may also form the basis of publications. Your data will be stored securely and anonymously by the SRUC and may be used in future research projects.

Spring barley does not need to be your main crop in order for you to participate in this survey – however, if you do not grow spring barley, please return this blank survey to the SRUC survey stand.

As management practices may vary from field to field within your farm, for example, due to poor drainage in one area, please complete the questionnaire based on what you consider to be your main practices.

The farmer survey runs from page 1 - 9. A separate survey for agronomists is on pages 10 – 16. Please only complete one.

If you would like to receive information about the results of this project directly, please tick the box and leave your contact details below.

□ I would like to receive information about the results of this project directly

If you are open to being contacted for a follow-up survey or clarification about your answers, please tick the box and leave your contact details below.

□ You may contact me for follow up questions

Your input will always remain anonymous.

Name (optional): _____

Email (optional): _____

Telephone number (optional): _____

Section 1: Demographic Questions

1. **What is your profession?**
   - □ Farmer
   - □ Agronomist (please skip to page 10)
   - □ Other – at this time we are only looking for responses from farmers or agronomists
2. **Age**

□ 16 – 24 □ 25 – 34 □ 35 – 44 □ 45 – 59 □ 60 – 74 □ 75+

3. **Education (tick highest applicable)**
   - □ Degree (BSc, BA, MSc, MA, PhD or equivalent)
   - □ Further education at college (HND, HNC, etc.)
   - □ Higher, A level, or equivalent
   - □ Standard grade, GSCE or equivalent
   - □ Vocational qualification
   - □ No qualifications
4. **Is your farm mixed animal and arable, or solely arable?**
   - □ Mixed
   - □ Arable
   - □ Animal only – at this time we are only looking for responses from arable and mixed farmers
5. **What size is your farm in total (including rented land)?**
   - □ 0 – less than 20 ha
   - □ 20 – less than 50 ha
   - □ 50 – less than 100 ha
   - □ 100 – less than 200 ha
   - □ 200 – less than 500 ha
   - □ 500 – less than 1000 ha
   - □ More than 1000 ha
6. **On average, how many hectares are devoted to spring barley in a given year?**
   - □ 0 – less than 20 ha
   - □ 20 – less than 50 ha
   - □ 50 – less than 100 ha
   - □ 100 – less than 200 ha
   - □ 200 – less than 500 ha
   - □ 500 – less than 1000 ha
   - □ More than 1000 ha
7. **What region is your farm located in?**
   - □ Eileanan an Iar
   - □ Highlands
   - □ Orkney
   - □ Shetland
   - □ Argyll and Bute
   - □ North East Scotland
   - □ Tayside
   - □ East Central
   - □ Fife
   - □ Lothians
   - □ Clyde Valley
   - □ Ayrshire
   - □ Dumfries & Galloway
   - □ Scottish Borders
   - □ Other, please specify: _____

8. **Which ONE of the following markets do you grow the majority of your spring barley for?**

□ Brewing
□ Distilling/Malting
□ Animal Feed
□ Human consumption

9. **Does your farm have any specific certifications/organisation affiliation or are you a member of any specific agri-environmental schemes** (please indicate all that apply, even if this is not applicable to the entire farm)

- Organic
- LEAF
- Agri-Environmental Scheme
- Other, please specify: _____

10. **Do you own or rent your farm?**

□ Own
□ Rent
□ Own ___hectares, rent ____ hectares
□ Other, please specify: _____

11. **What proportion of your spring barley is contract farmed?**

□ All □ Most □ Some □ A little □ None

Section 2: Varieties

12. **What spring barley varieties have you sown in the past 5 years?** Please list as many as you can remember – if you have sown multiple varieties in a given year, please order based on the number of hectares devoted to each, such that 1 has the largest acreage.

- 2015
  1.
  2.
  3.
- 2014
  1.
  2.
  3.
- 2013
  1.
  2.
  3.
- 2012
  1.
  2.
  3.
- 2011
  1.
  2.
  3.

13. **How important are the following to your decision about which variety(ies) of spring barley you plant?**

a. Agronomist suggestion

□ Very important □ Important □ Moderately important □ Of little importance □ Unimportant

b. Suggestion from/grown by another successful farmer in my area

□ Very important □ Important □ Moderately important □ Of little importance □ Unimportant

c. Market demand for a particular variety

□ Very important □ Important □ Moderately important □ Of little importance □ Unimportant

d. Having prior experience with the variety on my farm

□ Very important □ Important □ Moderately important □ Of little importance □ Unimportant

e. Varietal disease resistance rating

□ Very important □ Important □ Moderately important □ Of little importance □ Unimportant

f. Variety had malting/brewing certification

□ Very important □ Important □ Moderately important □ Of little importance □ Unimportant

For the purposes of questions 14 – 16, a disease resistant variety is defined as one with a minimum ranking of 7 out of 9 in the Scottish Cereals Recommended List for that year.

14. **In relation to Mildew, please indicate which ONE of the following statements best describes the spring barley varieties you sow**:
    - □ Only sow disease resistant varieties
    - □ Often sow disease resistant varieties
    - □ Sometimes sow disease resistant varieties
    - □ Rarely sow disease resistant varieties
    - □ Never sow disease resistant varieties
    - □ Unsure
15. **In relation to Ramularia, please indicate which ONE of the following statements best describes the spring barley varieties you sow**:
    - □ Only sow disease resistant varieties
    - □ Often sow disease resistant varieties
    - □ Sometimes sow disease resistant varieties
    - □ Rarely sow disease resistant varieties
    - □ Never sow disease resistant varieties
    - □ Unsure

16. **In relation to Rhynchosporium, please indicate which ONE of the following statements best describes the spring barley varieties you sow**:

□ Only sow disease resistant varieties
□ Often sow disease resistant varieties
□ Sometimes sow disease resistant varieties
□ Rarely sow disease resistant varieties
□ Never sow disease resistant varieties
□ Unsure

Section 3: Previous Rotations

17. **Rank the following factors in order of their influence on your decision to use a general crop rotation, with 1 being the most important and 6 the least important.** (If you do not use a rotation, please skip to the next question)

___ To reduce disease
___ I have always used this rotation
___ To spread risk of low yields/crop failure
___ Recommendation from an agronomist
___ Other successful farmers in my area use this rotation
___ Other, please specify: _____

18. **If you do not use a rotation, please rank the following reasons in terms of how large a part they play in your decision not to use a rotation, with 1 being the most important and 5 being the least important:** (if you use rotations, please skip onto the next question)

___ Lack of necessary equipment
___ Need to fulfil contracts for main crop
___ Do not think rotations are beneficial in terms of yield
___ Do not think rotations are beneficial in terms of disease
___ Other, please specify: _____

19. **Regardless of whether or not you use a rotation, how often do you sow barley in the same field for two or more consecutive seasons** (e.g. spring barley followed by spring barley?)

□ Always □ Often □ Sometimes □ Rarely □ Never

20. **How often do you sow cereals in the same field for two or more consecutive seasons** (e.g. winter wheat followed by winter barley?)

□ Always □ Often □ Sometimes □ Rarely □ Never

Section 4: Fungicide use

21. **How often do you apply fungicides to your spring barley crops?**

□ Every year □ Most years □ Some years □ Rarely □ Never

22. **Rank the following in in terms of their influence on your decision to apply fungicides to your spring barley crop, with 1 being the most important and 7 the least important:**

___ Weather forecasting

___ Independent expert advice (i.e. agronomist from SRUC, ADAS, AHDB, etc.)

___ Trade or distribution advice (i.e. representative from seed or pesticide company)

___ In-field assessment of growth stage

___ Other farmer's advice/actions

___ Spraying by calendar date

___ Other, please specify: _____

23. **How much (in t/ha) do you think fungicide use increases spring barley yields by?**

□ Less than one tonne per hectare
□ 1 - 2 tonnes per hectare
□ 2 - 3 tonnes per hectare
□ 3 - 4 tonnes per hectare
□ More than 4 tonnes per hectare

Section 5: Main Diseases on Farm

26. **How important to yield do you believe foliar diseases of spring barley to be?**

□ Very important □ Important □ Moderately important □ Of little importance □ Unimportant

27. **Which ONE of the following foliar diseases do you believe has been the most common on spring barley in the past five years?**

□ Powdery Mildew
□ Ramularia
□ Rhynchosporium

28. **Which ONE of the following foliar diseases do you consider to have impacted spring barley yield most in the past five years?**

□ Powdery Mildew
□ Ramularia
□ Rhynchosporium

Section 6: Fungicide Use in Future

28. Please indicate how strongly you agree/disagree with each of the following statements in relation to spring barley:

a. I think fungicide use can negatively impact the environment

□ Strongly agree □ Agree □ Neither agree nor disagree □ Disagree □ Strongly disagree

b. I am not concerned about fungicide use leading to fungicide resistance

□ Strongly agree □ Agree □ Neither agree nor disagree □ Disagree □ Strongly disagree

c. If I could use less fungicide and achieve the same yields, I would

□ Strongly agree □ Agree □ Neither agree nor disagree □ Disagree □ Strongly disagree

d. I have no concerns about the amount of fungicide I use on my spring barley

□ Strongly agree □ Agree □ Neither agree nor disagree □ Disagree □ Strongly disagree

e. If I could use less fungicide and have it be as cost-effective, I would

□ Strongly agree □ Agree □ Neither agree nor disagree □ Disagree □ Strongly disagree

f. I think finding methods to reduce fungicide use is important

□ Strongly agree □ Agree □ Neither agree nor disagree □ Disagree □ Strongly disagree

29. If the following measures were all cost-effective *alternatives* to using fungicides on spring barley:

a. Which would you be MOST likely to use on your farm?

	Choose ONE	
Sowing only disease resistant varieties	□ Most likely	□ N/A (already use)
Planned crop rotation	□ Most likely	□ N/A (already use)
Forecasting disease pressure for the season and changing management strategies based on these predictions	□ Most likely	□ N/A (already use)

b. Which would you be LEAST likely to use on your farm?

	Choose ONE	
Sowing only disease resistant varieties	□ Least likely	□ N/A (already use)
Planned crop rotation	□ Least likely	□ N/A (already use)
Forecasting disease pressure for the season and changing management strategies based on these predictions	□ Least likely	□ N/A (already use)

30. If the following measures were all cost-effective *complementary* techniques used alongside fungicides on spring barley:

a. Which would you be MOST likely to use on your farm?

	Choose ONE	
Sowing only disease resistant varieties	□ Most likely	□ N/A (already use)
Planned crop rotation	□ Most likely	□ N/A (already use)
Forecasting disease pressure for the season and spraying only when disease pressure will be high	□ Most likely	□ N/A (already use)

b. Which would you be LEAST likely to use on your farm?

	Choose ONE	
Sowing only disease resistant varieties	□ Least likely	□ N/A (already use)
Planned crop rotation	□ Least likely	□ N/A (already use)
Forecasting disease pressure for the season and spraying only when disease pressure will be high	□ Least likely	□ N/A (already use)

31. In terms of implementation for spring barley:

a. Which of the following measures do you think is MOST practical?

	Choose ONE
Sowing only disease resistant varieties	□ Most practical
Planned crop rotation	□ Most practical
Forecasting disease pressure for the season and spraying only when disease pressure will be high	□ Most practical

b.Which of the following measures do you think is LEAST practical?

	Choose ONE
Sowing only disease resistant varieties	□ Least practical
Planned crop rotation	□ Least practical
Forecasting disease pressure for the season and spraying only when disease pressure will be high	□ Least practical

32. In terms of cost of implementation for spring barley:

a. Which of the following measures do you think is MOST practical?

	Choose ONE
Sowing only disease resistant varieties	□ Most practical
Planned crop rotation	□ Most practical
Forecasting disease pressure for the season and spraying only when disease pressure will be high	□ Most practical

b. Which of the following measures do you think is LEAST practical?

	Choose ONE
Sowing only disease resistant varieties	□ Least practical
Planned crop rotation	□ Least practical
Forecasting disease pressure for the season and spraying only when disease pressure will be high	□ Least practical

Any other comments:

Thank you for taking the time to complete this survey. Please return it to the SRUC stand over the course of the day.

Agronomist Survey

Section 1: General Questions

1. **In what region(s) do you mostly advise farmers (tick all that apply)?**
   - □ Eileanan an Iar
   - □ Highlands
   - □ Orkney
   - □ Shetland
   - □ Argyll and Bute
   - □ North East Scotland
   - □ Tayside
   - □ East Central
   - □ Fife
   - □ Lothians
   - □ Clyde Valley
   - □ Ayrshire
   - □ Dumfries & Galloway
   - □ Scottish Borders
   - □ Other, please specify (for anyone outside Scotland)
2. **What products form the majority of your expertise (tick all that apply)?**
   - □ Wheat
   - □ Winter Barley
   - □ Spring Barley
   - □ Oats
   - □ Oilseed Rape
   - □ Triticale
   - □ Vegetables
   - □ Potatoes
   - □ Peas/beans
   - □ Fruits
   - □ Animals/animal products
   - □ Other, please specify: _____
3. **For which ONE market is the majority of spring barley you discuss destined?**
   - □ Brewing
   - □ Distilling
   - □ Animal Feed
   - □ Human consumption
4. **Do you work on mixed farms, or solely arable?**
   - □ Mixed farms only
   - □ Some mixed farms, some arable farms
   - □ Arable farms only
5. **Are you affiliated with/a member of any professional organisations?**
   - □ Scottish Agronomy
   - □ Association of Independent Crop Consultants
   - □ SAC consulting
   - □ Trade/distribution
   - □ Other, please specify: _____

Section 2: Varieties

6. **What spring barley varieties have you advised farmers to sow in the past 5 years?** Please list as many as you can remember – if you have advised multiple varieties in a given year, please order based on the most commonly suggested, such that 1 was the variety you suggested to most farmers that year.

- 2015
    1.
    2.
    3.
- 2014
    1.
    2.
    3.
- 2013
    1.
    2.
    3.
- 2012
    1.
    2.
    3.
- 2011
    1.
    2.
    3.

7. **Please rank the following in terms of their importance to your decision about which variety(ies) of spring barley you recommend, with 1 being the most important and 5 being the least important:**

___ Suggestion from/grown by another successful farmer in the area

___ Having prior experience with the variety on client farms

___ Varietal disease resistance rating

___ Variety had malting/brewing certification

___ Other, please specify: _____

For the purposes of questions 8 – 10, a disease resistant variety is defined as one with a minimum ranking of 7 out of 9 in the Scottish Cereals Recommended List for that year.

8. **In relation to Mildew, please indicate which ONE of the following statements best describes the spring barley varieties you recommend to farmers:**

□ Always suggest disease resistant varieties
□ Often suggest disease resistant varieties
□ Sometimes suggest disease resistant varieties
□ Rarely suggest disease resistant varieties
□ Never suggest disease resistant varieties

9. **In relation to Ramularia, please indicate which ONE of the following statements best describes the spring barley varieties you recommend to farmers:**
    - □ Always suggest disease resistant varieties
    - □ Often suggest disease resistant varieties
    - □ Sometimes suggest disease resistant varieties
    - □ Rarely suggest disease resistant varieties
    - □ Never suggest disease resistant varieties
10. **In relation to Rhynchosporium, please indicate which ONE of the following statements best describes the spring barley varieties you recommend to farmers:**
    - □ Always suggest disease resistant varieties
    - □ Often suggest disease resistant varieties
    - □ Sometimes suggest disease resistant varieties
    - □ Rarely suggest disease resistant varieties
    - □ Never suggest disease resistant varieties

Section 3: Previous Rotations

11. **Rank the following factors in order of their influence on your decision to recommend using a general crop rotation, with 1 being the most important and 4 the least important** (If you do not recommend using rotations, please skip this question)
    - ___ To reduce fungal disease
    - ___ Historic use of rotations in the area
    - ___ Other farmers in the area use this
    - ___ Other, please specify: _____
12. **If you do not recommend using a rotation, please rank the following reasons in terms of how large a part they play in your decision not to recommend rotations, with 1 being the most important and 5 being the least important:**
    - ___ Lack of necessary equipment
    - ___ Need to fulfil contracts for main crop
    - ___ Do not think rotations are beneficial in terms of yield
    - ___ Do not think rotations are beneficial in terms of fungal disease
    - ___ Other, please specify
13. **Regardless of whether or not you recommend rotations, how often do you suggest sowing barley in the same field for two or more consecutive seasons** (e.g. winter barley followed by winter barley?)

□ Always □ Often □ Sometimes □ Rarely □ Never

14. **How often do you suggest sowing cereals in the same field for two or more consecutive seasons** (e.g. winter wheat followed by winter barley?)

□ Always □ Often □ Sometimes □ Rarely □ Never

Section 4: Fungicide use

15. **Which ONE of the following statements best describes how often you recommend fungicide use for foliar diseases in spring barley?**

Every year to:	**Most years to:**	**Some years to:**	**Rare years to:**	□ **Never**
□ Every client	□ Every client	□ Every client	□ Every client	
□ Most clients	□ Most clients	□ Most clients	□ Most clients	
□ Some clients	□ Some clients	□ Some clients	□ Some clients	
□ Rare clients	□ Rare clients	□ Rare clients	□ Rare clients	

16. **Rank the following in in terms of their influence on your decision to recommend applying fungicides to spring barley, with 1 being the most important and 6 the least important:**

___ Weather forecasting

___ Independent expert advice/information (i.e. SRUC, ADAS, AHDB, etc.)

___ On-farm assessment of crop growth stage

___ Trade or distribution advice/information (i.e. seed or pesticide company)

___ Spraying by calendar date

___ Other successful farmer's actions in the area

17. **How much (in t/ha) do you think fungicide use for foliar diseases increases spring barley yields by?**

□ Less than one tonne per hectare
□ 1 - 2 tonnes per hectare
□ 2 - 3 tonnes per hectare
□ 3 - 4 tonnes per hectare
□ More than 4 tonnes per hectare

Section 5: Main Diseases on Farm

19. **How important to yield do you believe foliar diseases of spring barley to be?**

□ Very important □ Important □ Moderately important □ Of little importance □ Unimportant

20. **Which ONE of the following foliar diseases do you believe to have been the most common on spring barley in Scotland in the past five years?**

□ Powdery Mildew
□ Ramularia
□ Rhynchosporium

21. Which ONE of the following foliar diseases do you consider to have impacted spring barley yield most in Scotland in the past five years?

□ Powdery Mildew

□ Ramularia

□ Rhynchosporium

Section 6: Fungicide Use in Future

22. Please rank the following according to how strongly you agree/disagree in relation to spring barley:

a. I think fungicide use can negatively impact the environment

□ Strongly agree □ Agree □ Neither agree nor disagree □ Disagree □ Strongly disagree

b. I am not concerned about fungicide use leading to fungicide resistance

□ Strongly agree □ Agree □ Neither agree nor disagree □ Disagree □ Strongly disagree

c. If using less fungicide could achieve the same yields, I would recommend using less fungicide to farmers

□ Strongly agree □ Agree □ Neither agree nor disagree □ Disagree □ Strongly disagree

d. I have no concerns about the amount of fungicides farmers use on spring barley

□ Strongly agree □ Agree □ Neither agree nor disagree □ Disagree □ Strongly disagree

e. If using less fungicide was as cost-effective, I would recommend using less fungicide to farmers

□ Strongly agree □ Agree □ Neither agree nor disagree □ Disagree □ Strongly disagree

f. I think finding methods to reduce fungicide use is important

□ Strongly agree □ Agree □ Neither agree nor disagree □ Disagree □ Strongly disagree

23. If the following measures were all cost-effective *alternatives* to using fungicides on spring barley:

a. Which would you be MOST likely to recommend to farmers?

	Choose ONE	
Sowing only disease resistant varieties	□ Most likely	□ N/A (already recommend)
Planned crop rotation	□ Most likely	□ N/A (already recommend)
Forecasting disease pressure for the season and changing management strategies based on these predictions	□ Most likely	□ N/A (already recommend)

b. Which would you be LEAST likely to recommend to farmers?

	Choose ONE	
Sowing only disease resistant varieties	□ Least likely	□ N/A (already recommend)
Planned crop rotation	□ Least likely	□ N/A (already recommend)
Forecasting disease pressure for the season and changing management strategies based on these predictions	□ Least likely	□ N/A (already recommend)

24. If the following measures were all cost-effective *complementary* techniques used alongside fungicides on spring barley

a. Which would you be MOST likely to recommend to farmers?

	Choose ONE	
Sowing only disease resistant varieties	□ Most likely	□ N/A (already recommend)
Planned crop rotation	□ Most likely	□ N/A (already recommend)
Forecasting disease pressure for the season and spraying only when disease pressure will be high	□ Most likely	□ N/A (already recommend)

b. Which would you be LEAST likely to recommend to farmers?

	Choose ONE	
Sowing only disease resistant varieties	□ Least likely	□ N/A (already recommend)
Planned crop rotation	□ Least likely	□ N/A (already recommend)
Forecasting disease pressure for the season and spraying only when disease pressure will be high	□ Least likely	□ N/A (already recommend)

Any other comments:

Thank you for taking the time to complete this survey. Please return it to the SRUC stand over the course of the day.

***Response to Reviewers**

Reviewer #1: The manuscript "Perception vs practice: farmer attitudes towards and uptake of IPM in Scottish spring barley" submitted to Crop Protection by Stetkiewicz et al. is well-written, relevant and largely comprehensive.

The manuscript requires some minor clarifications that are listed below.

Page 2, line 4: initials of first names of authors are not needed here.

- These have been removed

Page 2, lines 23/24: This sentence is not clear. Authors, please rephrase it.

- This sentence has been rephrased, and is now on page 2, lines 22 - 23. It now reads: "In light of these policy changes, it is useful to consider the issues surrounding uptake and interest of stakeholders in IPM."

Page 3: Please briefly explain what a convenience sample (people who are easy to reach) is.

- To address this, a parenthetical aside has been added on page 3, lines 20 - 21: It reads: "(a non-random sample of individuals who are selected based on ease of sampling)"

Page 7: Which of the disease studied here occur most frequently in the area surveyed? Which of them caused most damage? If mildew should be the most frequent and most damaging disease, would there still be the discrepancy between perception and practice claimed in the manuscript? Authors, please try providing some numbers on the relative importance of the three diseases in the area surveyed.

- A brief overview of the importance of these three diseases and estimates of their impact on yield has been added to page 3, lines 1 – 7. It reads: "These are the three most commonly targeted diseases by Scottish farmers when applying fungicides to spring barley (Scottish Government, 2014). Yield reductions due to mildew have been recorded in the range of 11 – 17% for susceptible varieties (Lim & Gaunt, 1986; Hysing et al., 2012); reductions of 30 – 40% due to Rhynchosporium (Shipton et al., 1974, cited in Zhan et al., 2008); and Ramularia losses in the UK have been noted at 7 – 13% (Oxley et al., 2008), though reductions of up to 70% have been reported due to severe epidemics in South America (Pereyra 2013 cited in Havis et al., 2015)."
- However, regardless of which disease is most common/has the greatest impact on yield, the surveyed farmers stated that they believed Rhynchosporium to be the most common and have the greatest impact on yield (page 6, lines 21 - 23), so the disparity between this statement and their practices (e.g. not sowing varieties which are resistant to Rhynchosporium) remains.

Page 8:, line 4: A reference is missing here.

- This was a formatting error which has been resolved.

Page 9: Authors, please provide some estimates what a yield difference of 1-2 tons/ha means in terms of %. You may wish comparing your yield difference estimates with the figures published by Oerke (DOI: https://doi.org/10.1017/S0021859605005708). Are there any measurements available that could reveal if the respondents' estimate of the yield gain due to fungicide use was realistic? For instance in winter wheat, the effect of fungicide use was around 11-12% (https://doi.org/10.1016/j.cropro.2012.07.015). Does that compare to your figures?

- An estimate of the yield difference of 1-2 t/ha as a percent has been provided on page 11, lines 8 – 11. It reads: "Given the average estimated yield of spring barley in Scotland of

5.7t/ha, based on data from 2010 – 2014 (Scottish Government, 2015), farmers and agronomists therefore perceive a yield benefit of between 17.5 – 35% from fungicide use."

- The only citation found which presents yield increases due to fungicide use in spring barley is presented and discussed in relation to farmer estimates of yield gain on page 17, lines 1 – 3. It reads: "Previous work on spring barley production in England found yield increases of 2.4 – 13.8% due to fungicide use (Priestley and Bayles, 1982), suggesting farmer perception of fungicide use as increasing yields by 17 – 35% may be an overestimation. However, more recent field trial information is needed to make a full comparison, in order to account for changes in chemistry and cultivars."

Reviewer #2: Manuscript Number: CROPRO-D-17-00249 Remarks The manuscript is of good interest, regarding the IPM issues. Results are interesting and show farmers perception in terms of diseases damages and managements. However, it lacks appropriate methodologies for example there is no statistical analysis to show to which extent means are different from one another. Tables and figures shown here lacked statistical analysis, and are then not valuable statistically. Discussions based on these Results are therefore not acceptable.
Recommendation: Statistical analysis is needed and Results will be presented and discussed accordingly. After that the manuscript could be submitted again.

- In response to this comment, several actions were taken.
    - A sentence was added to the methods section, on page 5, lines 6-8, to highlight the reason for the limited use of statistical analysis of survey results in this paper. This sentence reads: "Due to the small sample size and the use of a non-random sampling method, statistical analysis is presented only where the sample size is thirty or above."
    - Where appropriate, that is, where there is a sample size of thirty or above, additional statistical analysis has been undertaken and added to the paper. The additions were:
        - average rank of 1.77, standard error: 0.19 (page 9, line 16)
        - average rank of 2.375, standard error: 0.13 (page 9, line 17)
    - Simulations of random varietal disease resistance ratings were created, and compared with the results from the survey, in order to determine both the probability of obtaining resistance ratings at least as high as what was reported by stakeholders by chance, and the probability of obtaining varietal disease resistance as low as what was reported by stakeholders by chance, if they were selecting highly resistant varieties.
        - This is reported in the methods section, see page 5, lines 9 - 25
        - Results are reported in the results section, see page 7, lines 16 – 22, and Table 2 (page 8) and Table 3 (page 9)
        - This is included in the discussion, see page 16, lines 3-6
    - Chi-square tests were used to compare survey results from agronomists and farmers, in order to determine whether there were significant differences in attitudes/perceptions between the two groups.
        - This is reported in the methods section, see page 5, lines 26 - 29
        - Results are reported in the results section, see page 10, lines 13 – 20; page 11, lines 6-8; page 11, lines 23 – 24, and page 12, lines 1 – 9
        - This is included in the discussion, see page 15, lines 22 – 24; page 16, lines 25 – 31