Current perspectives on the impact of weed seed contamination in sheep

Jane E. Kelly[1,2], Jane C. Quinn[1,2], Panayiotis Loukopoulos[1,2], Sharon G. Nielsen[3], Paul Weston[1,2], John C. Broster[1,2] and Leslie A. Weston[2]
[1] Charles Sturt University, Locked Bag 588, Wagga Wagga, New South Wales 2678, Australia
[2] Graham Centre for Agricultural Innovation, Charles Sturt University, Locked Bag 588, Wagga Wagga, New South Wales 2678, Australia
[3] QCU, Research Office, Charles Sturt University, Locked Bag 588, Wagga Wagga, New South Wales 2678, Australia
(janekelly@csu.edu.au)

Summary Grass seed contamination of sheep carcasses and skins results in significant losses across the Australian lamb and mutton value chains. Seven grass species found across Victoria (VIC) and New South Wales (NSW) are known to significantly impact carcass quality, with barley grass and brome grass as key perpetrators. To evaluate current trends associated with carcass weed seed contamination, extensive abattoir datasets (2009–2014) provided by Animal Health Australia (AHA) were analysed by state and biogeographic region. Significant differences in regional infestation were noted, with reduced contamination observed in Tasmania (TAS) and VIC in contrast to other states. No significant differences were observed in contamination between NSW and Queensland (QLD). Highest contamination occurred throughout the mixed cropping and pastoral zones, with notable events also in the high rainfall zone. Sex and age of animal were identified to have impacted seed contamination. These findings have implications for integrated weed management (IWM) strategies for weed species of importance to the livestock production chain.

Keywords Sheep, seed contamination, barley grass, brome grass, carcass, invasive weed.

INTRODUCTION

Physical damage from grass seed contamination in sheep results in reductions in wool and carcass quality in Australian flocks, through lodgement of seed within fleece, skin, carcass, and organs of grazing sheep. Direct and indirect costs are incurred by both producers and processors due to contamination (Collins 2013). Barley grass (*Hordeum* spp. Link.) and brome grass (*Bromus* spp. Roth.) are two species recently listed in the top 20 summer fallow weeds of crops in Australia (Llewellyn *et al*. 2016) and are also associated with carcass damage in Australia. The prevalence of both species is increasing across southern Australia, with some populations displaying herbicide resistance and variable seed dormancy (Gill and Blacklow 1985, Fleet and Gill 2012, Owen *et al*. 2015). Little information on the regional severity of seed contamination is currently available, limiting capacity to regionally tailor research efforts to match changing weed dynamics. To address this issue, statistical analyses were performed on abattoir datasets for seed-contaminated sheep located across Australian states provided by Animal Health Australia as part of the National Sheep Health Monitoring Project. Weed survey data was also spatially joined to identify associations between the distribution of barley grass and brome grass seed in sheep and existing weed infestations.

MATERIALS AND METHODS

Datasets All available abattoir datasets detailed the numbers of animals with significant grass seed lesions across all Australian agro-ecological zones during the period of 2009–2014. Barley grass and brome grass population density and distribution data from 2007 to 2015 were obtained using the methods described by Llewellyn *et al.* (2009) and were combined with abattoir datasets for New South Wales (NSW), Victoria (VIC), South Australia (SA) and Tasmania (TAS) using ArcGIS Desktop (ESRI, 2015) for spatial representation. Natural breaks (Jenks) classification was used to create classes of infestation levels within each map.

Analysis To explore the relationship between the percentage of carcass infestation (PIN) and the predictor variables (state, region and age) linear mixed models were used. The predictor variable was fitted as a fixed factor and the abattoir was fitted as a random variable in the model. The validity of conclusions from statistical analysis is dependent on the validity of the assumptions associated with the analysis; in this case the linear mixed model assumptions are: 1) that the residuals are normally distributed, 2) they have a constant variance and 3) they are independent. It is assumed that the factor level variances are equal for the predictor variable. It was necessary to use a natural logarithm to transform the response data and a weighted least squares analysis to correct for

heterogeneity of variance. A significance level of 5% was used for reporting results.

RESULTS

Seed contamination in Australian sheep, averaged over states and territories, was 23.3% of lambs, ewes and male animals. Significant differences in the incidence of weed seed carcass contamination was noted between states ($P < 0.001$), and also within states for NSW, VIC, South Australia (SA) and Western Australia (WA) only.

The predicted means for individual states show that contamination levels in WA (19.0% ± 1.3) were not significantly different to NSW (14.9% ± 1.2), Queensland (QLD) (14.1% ± 1.2), VIC (11.2% ± 1.2) or SA (18.1% ± 1.2), but were significantly higher than levels in TAS (9.2% ± 1.2). No significant difference was observed in seed contamination between sheep surveyed from TAS and VIC or between QLD and NSW. Predicted means for seed contamination by region showed the majority of contamination to be distributed across regions designated as mixed farming and/or pastoral zones. Greatest contamination was observed in WA regions, while southern SA, central western NSW and central QLD regions also showed high incidence of contamination (Figure 1). Regions in southeastern Australia showed high incidence of barley grass and brome grass infestation, and were positively correlated with regions displaying high carcass contamination (Figure 2).

Significant effects of sex and age of animal were also noted. Carcass contamination levels were highest in animals greater than two years of age and also in animals of 'unknown' age. Levels were lowest for animals under two years of age and for groups of mixed

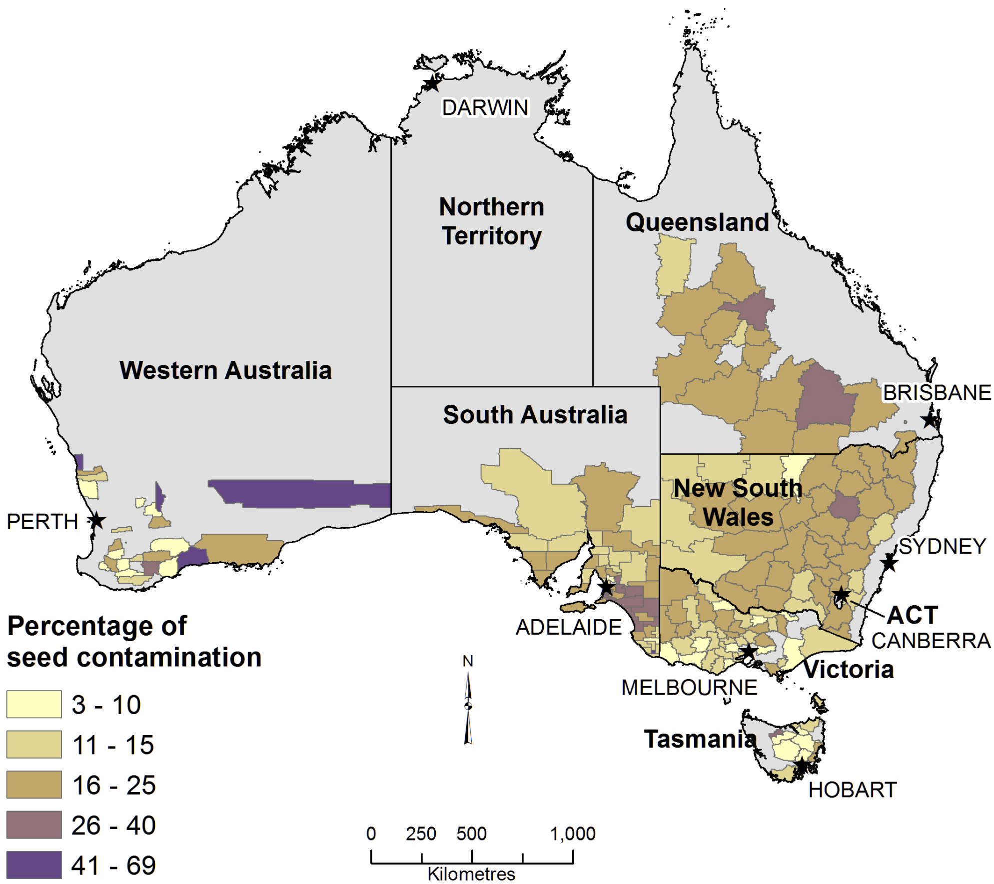

Figure 1. Distribution and the total density of sheep carcasses showing weed seed contamination between 2008 and 2014.

age (Table 1). Contamination levels were higher for all entire males and lower for castrated males than all other sex groups (Table 2). Contamination levels in females were not different to those of mixed or unknown sex groups (Table 2) but were significantly higher than in castrated males and lower than in entire males.

Table 1. Mean percentage of animals contaminated with weed seed by age group.

Age group	Mean percentage carcass contamination by weed seed (%) ± SE
Mixed age	11.3 ± 1.202 a
<2 years	12.4 ± 1.655 a
Unknown	13.6 ± 1.169 ab
>2 years	15.2 ± 1.168 b

Values with the same letter within each group are not significantly different (P <0.05).

Table 2. Mean percentage of animals contaminated with weed seed by sex group.

Sex group	Mean percentage carcass contamination by weed seed (%) ± SE
Castrated male	12.5 ± 1.161 a
Mixed sex	13.9 ± 1.159 b
Female	14.3 ± 1.160 bc
Unknown	16.4 ± 1.165 c
Entire male	24.0 ± 1.170 d

Values with the same letter within each group are not significantly different (P <0.05).

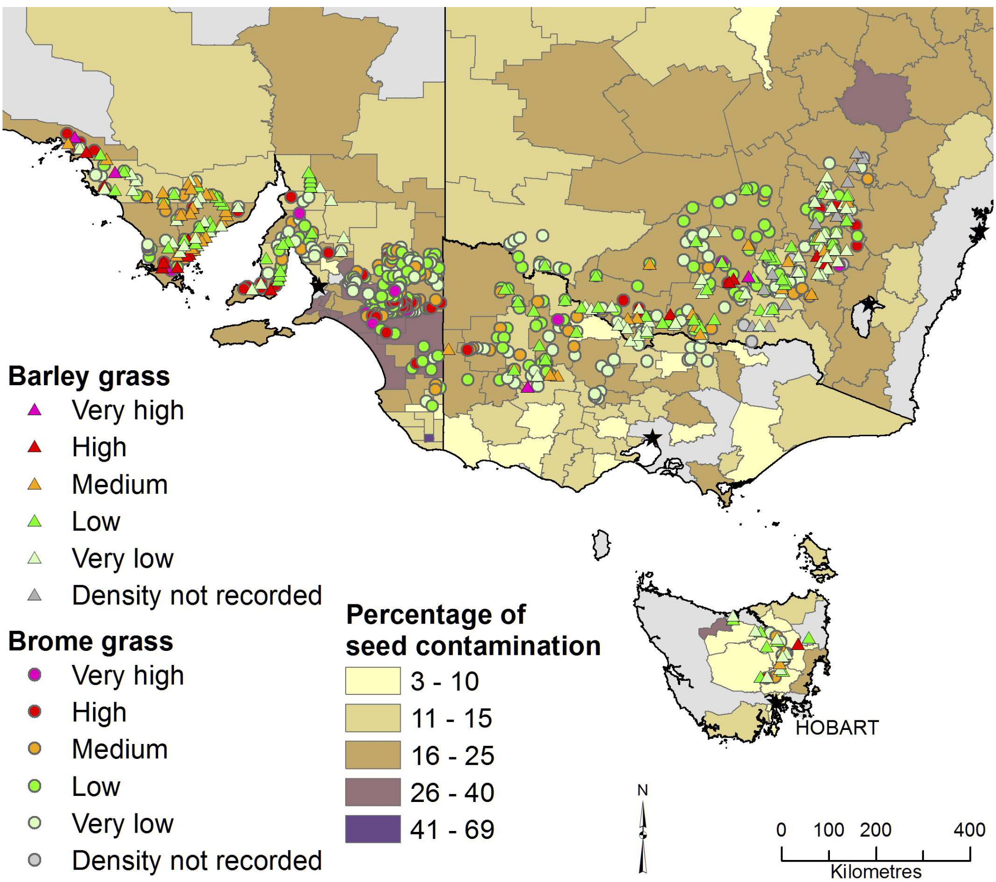

Figure 2. Regional distribution within NSW, VIC, TAS and SA of total density of carcass contamination combined with distribution of barley grass and brome grass populations across southeastern Australia between 2007 and 2015.

DISCUSSION

Key regional differences noted in WA, SA, VIC and NSW revealed that the highest incidence of contamination occurred within discrete regions within each agro-ecological zone. Widespread seed contamination occurred throughout Australia's pastoral zone and mixed farming zone where grain cropping and sheep production are typically concentrated (Puckridge and French, 1983). Barley grass and brome grass are annual weeds associated with carcass damage and are also common in pastures and grain crops in southern mixed farming regions (Broster *et al.* 2012). The distribution patterns of weed infestation and carcass contamination observed in this study are also in agreement with the findings of Llewellyn *et al.* (2016), who identified barley grass and brome grass as two of the most problematic weeds of grain crops in southern and western Australia. Given the strong integration of grain cropping with sheep production in the mixed farming zone, the potential for carcass contamination by contact with barley grass and brome grass is high. Consequently, it is not surprising that the distribution of weed infestation was spatially associated with regions displaying higher weed seed contamination, highlighting the significance of barley grass and brome grass in causing carcass damage in Australia.

The lack of differences in seed contamination between NSW and QLD and between TAS and VIC may be associated with early seed contamination of QLD and TAS re-stocker animals before they are transported (East and Foreman 2011) and identified as NSW and VIC sheep upon slaughter. Additional experimentation to determine specifically when and where highest rates of contamination occur in young stock is required to draw meaningful conclusions about seed source populations.

High contamination levels associated with sex and age were likely due to the length of exposure of sheep to infested sites producing ample weed seed. Males and females over two years of age and entire males sold for slaughter (normally cast for age rams), typically experience longer periods of seed exposure. Animals under two years of age commonly comprise castrated males and females sold for slaughter into the lamb market before considerable seed exposure. Variable contamination in all other groups was likely associated with variable age of sheep comprising each group and the associated variation in the length of exposure to mature weeds producing seed.

Increased weed seed contamination in sheep by barley grass and brome grass is potentially associated with changes in rainfall patterns and farming practices in recent years. Increased variation in rainfall, as evidenced by drier autumns and prolonged periods of drought, coupled with warmer temperatures and higher soil moisture evaporation rates are experienced across southern Australia (Murphy and Timbal 2008) and may limit growth of desirable pasture species. Weed populations displaying variable dormancy patterns, drought tolerance and rapid germination, are likely to be highly competitive in such conditions. Barley grass and brome grass also potentially utilise such mechanisms to enhance survival under the climatic stresses of southern Australia (Rumball 1971, Gill and Blacklow 1985).

In addition, the adoption of reduced tillage, strong reliance on herbicides and earlier sowing of grain crops have also likely selected for barley grass and brome grass biotypes now displaying herbicide resistance and variable seed dormancy (Gill and Blacklow 1985, Fleet and Gill 2012, Owen *et al.* 2015). High incidence of carcass contamination in the pastoral and high rainfall regions is also possibly due to seed dispersal from mixed farming regions via attachment of seed to fleece during animal movement and transport.

Anatomically, barley grass and brome grass seed possess long awns, enabling them to easily adhere to fleece and later penetrate dermal tissues. Specialty lamb producers and traders in the high rainfall zone and properties within the pastoral zone also often introduce large numbers of sheep from adjacent mixed farming regions (East and Foreman 2011) that are possibly already contaminated with seed upon arrival. Both weed species display significant phenotypic plasticity across Australia, and readily germinate and establish across all regions. Higher infestation rates in the high rainfall zones may be assisted by overgrazing, reduced soil fertility and the use of less competitive pasture legumes or legume mixtures.

Focused chemical and rotational strategies to manage these weeds could be employed in areas of high weed infestation to result in reduced infestation to carcasses over time. Future research into the development of focused IWM strategies will be essential for regional control of these weeds and their biotypes, permitting a more targeted approach in reducing seed contamination in Australia.

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