Seed contamination in sheep: new investigations into an old problem

by Kelly, J.E., Quinn, J.C., Loukopoulos, P., Broster, J.C., Behrendt, K. and Weston, L.A.

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Complete List of Authors:	Kelly, Jane; Charles Sturt University - Wagga Wagga Campus, Animal and Veterinary Sciences; The Graham Centre for Agricultural Innovation, Charles Sturt University and New South Wales Department of Primary Industries Quinn, Jane; Charles Sturt University - Wagga Wagga Campus, Animal and Veterinary Sciences; The Graham Centre for Agricultural Innovation, Charles Sturt University and New South Wales Department of Primary Industries Loukopoulos, Panayiotis; Charles Sturt University - Wagga Wagga Campus, Animal and Veterinary Sciences; The Graham Centre for Agricultural Innovation, Charles Sturt University and New South Wales Department of Primary Industries Broster, John; Charles Sturt University, School of Agricultural and Wine Sciences Behrendt, Karl; Harper Adams University College Weston, Leslie; The Graham Centre for Agricultural Innovation, Charles Sturt University and New South Wales Department of Primary Industries

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Seed contamination in sheep: new investigations into an old problem

J.E. Kelly [A,B*] J.C. Quinn [A,B], P. Loukopoulos [A,B], J.C. Broster [A,B], K. Behrendt [A,B,C] and L. A. Weston [B]

[A] Charles Sturt University, Locked Bag 588, Wagga Wagga, New South Wales 2678, Australia

[B] Graham Centre for Agricultural Innovation, Charles Sturt University, Locked Bag 588, Wagga Wagga, New South Wales 2678, Australia

[C] Harper Adams University, Newport, Shropshire, TF10 8NB, United Kingdom

[*]Corresponding author. School of Agricultural and Wine Sciences, Charles Sturt University, PO Box 883, Orange, NSW, Australia. Tel.:+61 02 63 656 576 *E-mail address*: janekelly@csu.edu.au

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Seed contamination of sheep fleece and carcasses causes significant production losses. Recent studies indicate distribution and frequency of carcass damage across Australia are associated with the distribution of barley and brome grass populations, and varies with state, region, year, animal and climate factors. Reviewing the literature on this issue highlights areas requiring future research, including the investigation of effective weed management strategies for current Australian conditions.

Abstract. Seed contamination significantly impacts production capacity and animal welfare in Australian sheep flocks and causes considerable financial loss to producers and processors across sheepmeat value chains. Seven grass weed species contribute to seed carcass contamination in Australia, with barley grass (*Hordeum* spp.) identified as a key perpetrator. Herbicide resistance and variable dormancy emerging in southern Australian barley grass populations are thought to enhance its capacity for successful pasture invasion, further exacerbating the potential for seed contamination in sheep. This article reviews the current literature regarding the impact and incidence of seed contamination on sheepmeat production, with particular reference to key grass weed species prevalence across Australia. Data is presented on recent incidence of carcass contamination across years, where incidence varied between 11 and 80% from 2009 to 2013, contracting to between 2 and 60% during 2014 and 2015. Key areas requiring future research are defined. Understanding the biology of key grass weeds, historical influences and economic consequences associated with seed contamination in sheep may assist in defining future risks to sheep production and improve weed management. Furthermore, examining more recent data describing the current status of seed contamination across Australia and associations with causal weed species may aid the development of critical weed management strategies in highly infested regions, subsequently limiting the extent of future seed contamination.

Additional keywords: Sheepmeat, Sheep pelts, Carcass, Meat processing, Grasses

Introduction

Seed contamination in sheep refers to the penetration of body tissues by the seeds of certain grass weeds during grazing, which is an increasing problem within the Australian sheep industry. Affected sheep suffer considerable physical injury, including penetration of external tissues, carcass and internal organs. Consequently, an array of costs and losses are borne by producers and sheepmeat processors (Cornish and Beale 1974; Collins *et al.* 2013; Smith 2014). Affected sheep exhibit reduced growth rates, considerable weight loss and mortality (Dodd 1919; Atkinson and Hartley 1972; Hartley and Bimler 1975) and contamination of wool results in price discounts due to extra wool processing costs (Lunney 1983; Nolan *et al.* 2014).

Of the seven annual grass weed species known to contribute to seed contamination (Collins *et al.* 2013), barley grass (*Hordeum* spp. Link.) and brome grass (*Bromus* spp. Roth.) are frequently associated with carcass damage (Atkinson and Hartley 1972; Tozer *et al.* 2008). Furthermore, recent evidence suggests invasion capability has increased in barley grass and brome grass populations, a result of growing herbicide resistance and variable dormancy patterns in many Australian populations (Gill and Blacklow 1985; Fleet and Gill 2012; Boutsalis *et al.* 2014; Owen *et al.* 2015; Shergill *et al.* 2015b; Shergill *et al.* 2017a; Shergill *et al.* 2017b). These factors present challenges for effective management of both species, and lack of control may result in increased incidence of carcass damage.

This review examines historical and recent literature regarding factors influencing seed contamination and impacts upon sheepmeat production, so as to assist in identifying future research needs and / or mitigation strategies to reduce invasive grass infestation and carcass contamination.

Seed contamination in sheep

Seed contamination of sheep commonly occurs as a consequence of management or seasonal influences (Collins *et al.* 2013; George 1972; Kelly *et al*. 2016, Kelly 2016). When seeds dislodge from the plant's inflorescence due to disturbance by grazing, seed awns adhere to the fleece and animal movement aids seed transport to the skin, resulting in body tissue penetration (Fig.1). Grass seed dispersal often corresponds with highest rates of seed contamination (Warr 1980), which causes significant injury (Dodd 1919; Mulham and Moore 1970; Hartley and Atkinson 1972; Hartley and Bimler 1975; Little *et al.* 1992). The issue presents many welfare and production challenges which are not often realised until slaughter when carcass damage becomes visible.

Insert Fig 1 here

Problematic weed species contributing to seed contamination

The introduced and widely distributed weed, barley grass (*Hordeum* spp. Link.), has been historically problematic in contributing to seed contamination (Dodd 1919). Also implicated were the native grasses; spear grass (*Austrostipa* spp (Lindley) S.W.L. Jacobs and Everett), wire grass (*Aristida* spp. R. Br.) and silver grass (*Vulpia bromoides* (L). Gray) (Dodd 1919). Despite almost 100 years of research, all of these species continue to cause carcass damage (Collins 2013). While Storksbill (*Erodium* spp. (L.) L'Hér), Chilean needle grass (*Nasella neesiana* (Trin. & Rupr.)) and brome grass infestations (*Bromus* spp. Roth) also result in seed contamination, the following species; *Hordeum* spp., *Vulpia* spp., *Stipa* spp., and *Erodium* spp. are considered by sheepmeat processors as the major carcass contaminants in Australia (Collins 2013).

Brome grass and barley grass are currently listed within the top twenty residual weeds of southern Australian grain growing regions (Llewellyn *et al.* 2016). Interestingly, certain populations of these grasses are spreading due to herbicide resistance (Owen *et al.* 2015; Shergill *et al.* 2015a, 2016b; Shergill *et al.* 2017a; Shergill *et al.* 2017b) and variable seed dormancy patterns (Fleet and Gill 2012; Kleemann and Gill 2013) as a result of repeated herbicide exposure, changing farming practices (Fleet and Gill 2012; Recasens *et al.* 2016) and potential adaptation to variable climatic conditions (Smith 1968; Gill and Blacklow 1985). Brome grass and barley grass now inhabits over 1.4 million hectares and 244,000 hectares, respectively (Llewellyn *et al.* 2016).

Three barley grass subspecies are commonly found in Australia. They are collectively referred to as the *Hordeum murinum* complex (Cocks *et al.* 1976) comprised of *H. leporinum* Link. *H. glaucum* Steud. and *H. murinum* L. (Cocks *et al.* 1976). A less common fourth subspecies, *H. hystrix* Roth., is also noted within Australian National Herbarium collections (D Albrecht, pers. comm.).

Distribution of problematic weed species

Hordeum spp. (and *Vulpia* spp) are among the five most prevalent pasture weeds across the New South Wales perennial pasture zone (Dellow *et al.* 2002). Together with *Bromus* spp., they are common to southern New South Wales cropping regions (Lemerle *et al.* 1996; Broster *et al.* 2012b). *Bromus rigidus* frequently invades cropping fields, while *B. diandrus,* another injurious *Bromus* species, often occupies roadsides and disturbed areas (Kleemann and Gill 2006). *Hordeum glaucum* invades drier, semi-arid regions (<425 mm annual rainfall), *Hordeum leporinum* commonly occupies regions above 425 mm annual rainfall and *Hordeum murinum* most frequently inhabits Tasmania (Cocks *et al.* 1976). In Western Australia, both *Hordeum* spp. and *Bromus* spp. have colonised up to 64% of cropping fields (Borger *et al.* 2012), with 1-3% invading summer fallows (Michael *et al.* 2010). However, in northern NSW and Queensland *Hordeum* spp. are scarce, occurring in less than 1% of arable fields (Osten *et al.* 2007). Together, both species are noted at a frequency of less than 10% in Tasmania (Broster *et al.* 2012a).

Production loss, morbidity and animal welfare concerns associated with seed contamination

Previous reports highlight reduced growth rates and live weight losses of up to 11.5kg per head within three months in contaminated sheep (Mulham and Moore 1970; Campbell *et al.* 1972; Hartley and Atkinson 1972, 1973a; Hartley and Bimler 1975; Hartley 1976; Hamilton 1978; Little *et al.* 1992). Significant weight loss leads to reduced reproductive capacity in adults and restricts progeny growth (Behrendt *et al.* 2011). Seeds penetrate eyes causing inflammation (Dodd 1919; George 1972), blindness (Hartley and Atkinson 1972), facial injuries (George 1972; Hartley and Bimler 1975; Hartley 1976), skin abscesses and ulcerations (Dodd 1919; Belschner 1925; Loughnan 1964; Barry 1971). Seeds penetrating internal organs may also cause peritonitis, pleurisy (Dodd 1919; Loughnan 1964) and tetanus (Belschner 1925), while lameness occurs from seed penetration of the feet. Generalised inflammation and fever commonly occurs from seed wound infections and mortality rates are often significant (Mulham and Moore 1970; Cornish and Beale 1974; Hartley and Bimler 1975). Seed contamination also impacts animal welfare, where sheep may experience increased flystrike susceptibility and significant physical discomfort associated with seed injury (Dodd 1919; Loughnan 1964; Campbell *et al.* 1972).

Animal factors leading to seed contamination

Numerous physiological factors appear to influence seed contamination in sheep. Young animals and sheep with heavily wrinkled skin are predisposed to heavy contamination compared to older sheep or those carrying less skin wrinkle (Dodd 1919; Mulham and Moore 1970; Campbell *et al.* 1972; Shugg and Vivian 1973; Cornish and Beale 1974; Hartley and Bimler 1975). Studies also highlight the predisposition of Merino wool to seed attachment compared to Romney and Border Leicester wool types (Atkinson and Hartley 1972; Hartley and Atkinson 1973b; Shugg and Vivian 1973; Hartley and Bimler 1975; Hartley 1976), although seed attachment was not necessarily associated with fibre diameter (Hartley and Atkinson 1973b). Skins with longer wool commonly attract higher seed burdens in contrast to skins with shorter wool (Mulham and Moore 1970; Hartley and Atkinson 1973b; Shugg and Vivian 1973; Cornish and Beale 1974; Little *et al.* 1992; Mason *et al.* 2008; Mason and Behrendt 2009). Despite this, skins with longer wool generally attract higher prices due to the value placed on these skins in some markets (Mason *et al.* 2008).

Economic impacts of seed contamination in sheep

The economic impacts of seed contamination on farm have not been fully evaluated in Australia. Previous literature describes significant carcass, skin and wool price discounts incurred by producers as a result of seed contamination (Cornish and Beale 1974; Sloane *et al.* 1989; Collins 2013). Discounts between \$0.10 to \$1/kg carcass weight are commonly applied within abattoirs (Collins 2013), reducing carcass value per animal by up to \$6 per head (Little *et al*. 1992). In addition, costs associated with live weight loss on meat yield, fertility and wool production (Killeen 1976; Kellaway 1973), morbidity (Dodd 1919; Holmes 1993) and mortality (Dodd 1919; Campbell *et al.* 1972; George 1972) are also significant. Secondary costs include those associated with altered management to accommodate contaminated animals (Collins *et al.* 2013), herbicide application for weed control (Sloane *et al.* 1989) and reduced pasture availability for live weight gain after herbicide application (Hartley *et al.* 1974).

Impact of seed contamination upon the sheepmeat processing sector

Seed contamination is a key factor affecting abattoir profitability (Collins 2013), where incidence tends to be variable across years and is subject to seasonal influences upon seed production (Cornish and Beale 1974; Collins 2013). Seed contamination leads to carcass rejection by export markets, downgrading of meat products and the potential for loss of export licenses (Loughnan 1964; Shugg and Vivian 1973; Cornish and Beale 1974; Smith 2014). Sheepmeat markets require total seed removal from contaminated carcasses, reducing carcass weight by up to 4-5 kg and reducing meat yield as a consequence of excessive trimming (Loughnan 1964; Shugg and Vivian 1973). Additional trimming reduces throughput from slower chain speeds and increases labour costs by 60% (Collins 2013; Collins *et al.* 2013; Smith 2014). Although one sheepmeat processor reported an annual cost of $3 million to their business due to seed contamination (Collins 2013), many processors have estimated the cost to be $20-30 per carcass (Collins 2013). Seed contamination also affects pelt quality (Loughnan 1964; Mulham and Moore 1970; Rumball 1970; Atkinson and Hartley 1972) and value (Atkinson and Hartley 1972), which reduces market options (Collins *et al.* 2013).

Current trends in carcass seed contamination in Australia

Regional prevalence of seed contamination and associations with distribution of key grass weeds

Recent studies performed by the authors have utilised a national database (curated by Animal Health Australia) to explore the current factors affecting incidence and distribution of seed contamination in sheep carcasses across Australia. Analysis results revealed variable incidence across states and regions, with contamination noted most frequently across mainland states in contrast to Tasmania (Kelly *et al*. 2016; Kelly 2016). Contamination was associated with barley and brome grass distribution across the mixed farming and pastoral zones, a logical result given the presence of large adjoining sheep and cropping enterprises and the prevalence of both weed species across southern cropping regions (Llewellyn *et al.* 2016). Significant contamination of sheep in the high rainfall zone was also noted, suggesting the distribution of other key grass weeds producing penetrating seeds within this biogeographic zone. Also identified were significant effects of sheep sex and age on incidence of contamination (Kelly *et al*. 2016; Kelly 2016). Higher frequencies of contamination were noted in both sexes over two years of age and entire males sold for slaughter (cast for age rams) in contrast to younger sheep of either sex, likely due to the repeated exposure to seed in older animals as a result of the length of time on farm in contaminated paddocks. Incidence of seed contamination was also significantly influenced by both climatic factors and altitude, likely reflective of the variable ecological requirements of weeds associated with contamination and the seasonal variation in seed production and contamination (Kelly 2016).

Impact of year on the regional incidence of seed contamination

The results of this study also revealed significant differences in contamination across years throughout Queensland, New South Wales, Victoria and South Australian regions between 2009 and 2015 ($P < 0.001$, Fig. 2).

Insert Figure 2 here

Carcass contamination frequency across all states ranged between 11 and 80% between 2009 and 2013 and contracted during 2014 and 2015, to between 2 and 60%. The array of regions exhibiting contamination also generally increased from 2013 to 2015, likely a reflection of season and flock management (Collins 2013; George 1972). In 2009, the combination of significant rainfall events and warmer conditions signifying the end of the millennium drought (Bureau of Meteorology 2009, 2011, 2012) likely created conditions favourable for annual weed competition and proliferation (Kelly *et al.* 2016), leading to increased physical contact with sheep grazing these regions. Wetter seasonal conditions also led to increased sheep and lamb numbers (Caboche and Thompson, 2013) and reduced sheep slaughter numbers, leading to high retention of sheep on farm during 2010 and 2011 (Thomas and Matthews 2016), where exposure to ample seed produced by thriving weed populations was likely. This may explain the higher contamination frequency in certain regions during 2012, where slaughter of animals (likely contaminated with seed from the previous years), had increased due to dry conditions prevailing in the latter half of the year (Bureau of Meteorology 2012; Caboche and Thompson, 2013; Thomas and Matthews 2016;). The broader pattern of contamination observed between 2013 and 2014 possibly reflects the slaughter of previously contaminated sheep sourced from numerous regions with high weed infestation rates. During 2015, the reduced contamination across numerous states and regions may reflect higher lamb slaughter occurring earlier, due to seasonally dry conditions (Ashton *et al*., 2016), thereby reducing lamb exposure to seed. Given previous findings noting high frequencies of contamination in older sheep, reduced adult sheep slaughter during 2015 may also have contributed to lower contamination incidence during that year as a consequence of adults being retained on farm for flock re-building (Berry, 2015; Thomas and Matthews 2016).

Implications and future research directions

Climate variability, conservation tillage, and reliance on herbicides for weed management are factors likely to favour the spread of annual grass weeds across southern Australia, thus enabling selection for highly competitive biotypes. The increasing prevalence of seed dormancy and herbicide resistance occurring concurrently within grass weed populations will present additional challenges due to the lack of efficacious herbicide options (Shergill *et al*. 2015a). As sheep numbers increase across cereal cropping and pasture zones of Australia, these regions face increased rates of future carcass damage, potentially presenting risks for maintaining market access for quality sheepmeat products.

With the Australian sheep industry experiencing a re-building phase, older animals may be retained for longer periods. Creating safe paddocks for housing older animals will be important, as these animals potentially contribute to the spread of weed populations and high levels of carcass damage observed in Australian abattoirs. The procedural differences in data reporting between abattoirs highlights the importance of standardising data collection protocols during processing for more comprehensive monitoring of carcass damage.

Reducing the problem of seed contamination over the longer term will be achieved by effective and proactive control of causative weeds on farm and encouraging the establishment and productivity of competitive pasture species. It is increasingly important to ensure research and outreach efforts address early season weed management before seed set, with particular emphasis in heavily infested regions.

Given the increasing spread of barley grass across southern Australia and its dominant role in sheep carcass damage, cost effective cultural and chemical management strategies should target *Hordeum spp*. Currently, species distribution across Australia is unknown and complicated by misidentification (Cocks *et al.* 1976). Therefore, accurate subspecies identification across all biogeographic regions would be valuable to develop species-specific control strategies for *Hordeum* spp. Given the frequency of barley grass infestations within legume pastures used for sheepmeat production, future research regarding the development of integrated control strategies and the identification of chemically diverse herbicides for barley grass control is needed within typical legume pastures. This is exacerbated by the increased prevalence of herbicide resistance in many populations (Owen *et al.* 2012; Shergill 2016; Shergill *et al.* 2016a; Shergill *et al.* 2017a; Shergill *et al.* 2017b).

To determine economically viable control strategies for weed management and reduce seed contamination rates, there is a need to develop an improved understanding of the changing nature of barley grass phenology in response to variable population dynamics. Studies relating barley grass density to morphology, phenology and fecundity will be critical, in addition to the use of dynamic bio-economic modelling to examine control efficiency and mitigation of seed contamination over the longer term.

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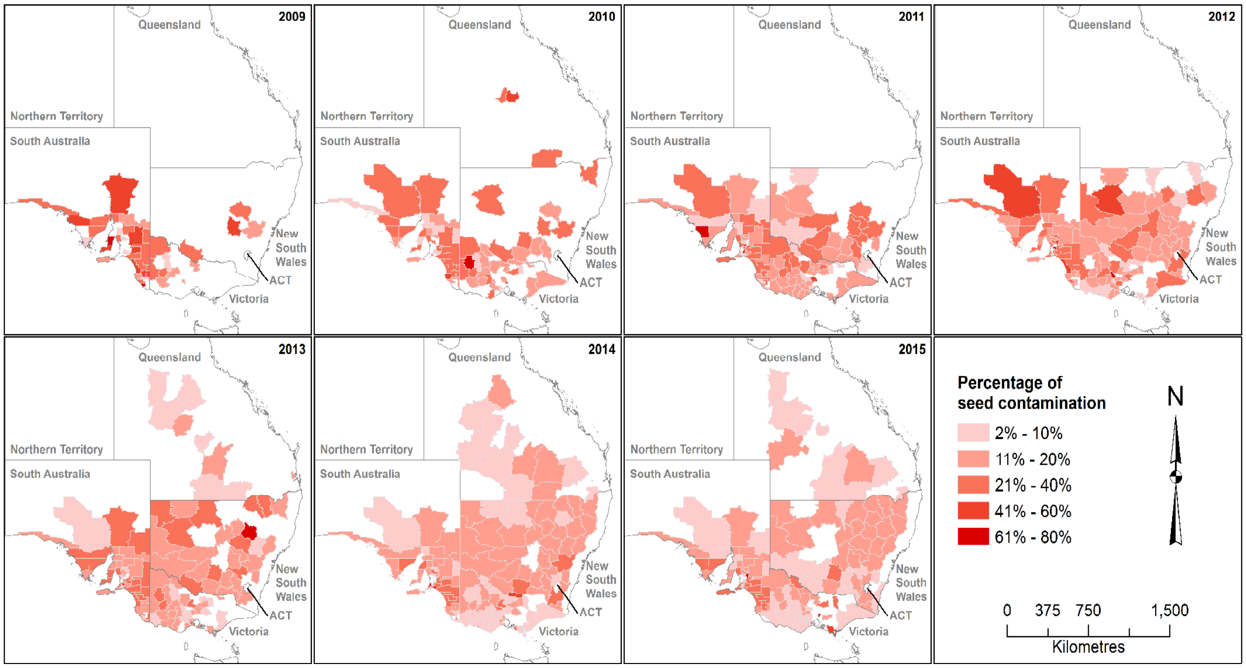
Figures

Fig 1. Significant penetration of the skin by barley grass seeds across the body of a young Merino sheep located in Central West New South Wales (photo courtesy of K. Behrendt).

Fig.2. Distribution and total density of sheep carcasses showing seed contamination during years 2009 to 2015. Darker discolouration indicates higher density of contamination.

Fig 1. Significant penetration of the skin by barley grass seeds across the body of a young Merino sheep located in Central West New South Wales (photo courtesy of K. Behrendt).



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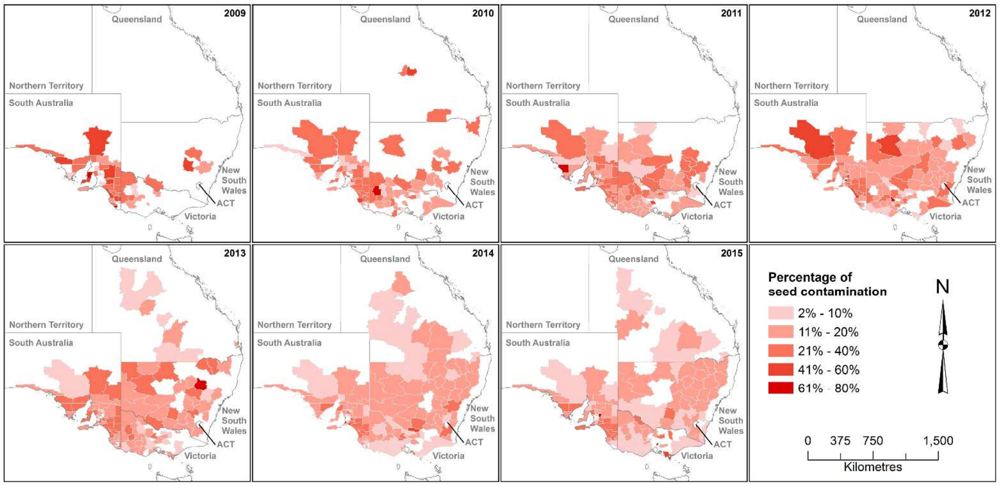
171x228mm (72 x 72 DPI)



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