Final points

I have made some simple points to get people thinking about the educational efforts about weeds. We have achieved much in community awareness over the last decade but we may be losing effectiveness. I would like to suggest that we consider well our weed education efforts and work for constant improvement. Let's keep working on new ideas to get our important messages about weeds and their control to the wider community.

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References

Bush, J., Rowan, H., Platt, D., and Vearing, L. Pest plants handbook. City of Whittlesea.

Casey, Greater Dandenong and Cardinia. Weed identification guide. City of Casey, City of Greater Dandenong and Cardinia Shire Council.

Dunnett, G. Banyule's environmental weeds. Banyule City Council.

Dunnett, G. (2002). Identify and help control environmental weeds. Shire of Yarra Ranges.

Knox Environment Society and The SGAP Foothills group. (1999). Pest plants: guide to identification and management of environmental weeds in Knox and Maroondah. Knox City Council, Maroondah City Council.

Knox Environment Society and The SGAP Foothills group. Environmental weeds in Knox. Knox City Council.

Loyn, R.H. and French, K. (1991). Birds and environmental weeds in south-eastern Australia. *Plant Protection Quarterly* 6(3), 137-49.

Manningham City Council (2000). Weed identification. City of Manningham.

Mornington Peninsula. Weeds of the Mornington Peninsula. Mornington Peninsula Shire Council.

Muyt, A. (2002). Bunyip State Park weed management strategies and issues. Report prepared by Practical Ecology Pty. Ltd. Alphington Victoria for Parks Victoria.

Nillumbik (2004). Environmental weeds. Nillumbik Shire Council.

Shepherd, R.C.H., Richardson, R.G. and Richardson, F.J. (2001). 'Plants of importance to Australia, a checklist'. (R.G. and F.J. Richardson, Melbourne).

Whitehorse City Council (n.d.). Weeds in Whitehorse. City of Whitehorse.

Wyndham (2003). Flora and fauna of Wyndham 2003. Wyndham City Council.

Weed seed dispersal by cattle and sheep

Rex Stanton, Charles Sturt University, Wagga Wagga, New South Wales 2678, Australia.

Introduction

Zoochory, or seed dispersal by animals, occurs in over 50% of all plant species (Tiffney and Mazer 1995). The fossil record suggests that mesozoic fauna ingested seeds and may be the first recorded seed dispersers (Tiffney 2005). Zoochory is advantageous to plants by providing an opportunity to disperse seeds further than can typically be achieved via abiotic methods.

Where suitable morphological seed characteristics are present, dispersal can occur via exozoochorous means. External transport can allow for dispersal distances ranging from tens of metres to kilometres through attachment to sheep (Fischer *et al.* 1996) or cattle (Couvreur *et al.* 2005). Couvreur *et al.* (2005) have suggested that seed retention time is generally not affected by environmental factors such as the weather or the vegetation community type, whereas there are interactions between seed morphology and the length of animal fur. Small, light seeds tend to be retained better in short fur, whereas larger heavy seeds, or seeds with many long appendages, are retained better in longer fur (Couvreur *et al.* 2005, Romermann *et al.* 2005).

Sorensen (1986) has suggested that species with adhesive disseminules suitable for exozoochorous dispersal are more likely to be low growing annuals from dry or disturbed habitats, as typified by a wide range of burrs. Cattle have been reported by Declerckfloate (1997) as being major dispersers of hound's-tongue (*Cynoglossum officinale* L.) burrs, a noxious weed from North America that grows to a height of 50 cm.

Endozoochorous methods, where seeds are ingested and pass through the gut, are the most common form of seed dispersal by animals, suggesting there is an innate ability of seeds to survive digestion. Hughes *et al.* (1994) suggest that such biotic dispersal is generally related to seed size, with larger seeds more likely to be dispersed by endozoochory than smaller seeds.

Weeds occur in all farming production systems, with a range of methods potentially available to reduce seed recruitment. Techniques for controlling viable seed set include chemical control (e.g. spray topping), mechanical control (e.g. slashing, tillage), seed collection at harvest, fodder conservation (hay or silage) and grazing. When seed is collected at harvest, the two main options for disposing of the collected seed are burning or feeding to livestock. Seed left in the paddock after harvest can also be spread by livestock, as sheep are capable of ingesting grain and seed scattered on the ground (Curtis and Mavrantonis 1990, Olson *et al.* 1997). With the exception of mechanical control or burning of collected seed, these methods rely on the remaining viable weed seeds being destroyed during the digestion process. Poorly digested seed may pass through the animal in the faeces in germinable condition, leading to either weed reinfestation in the original field, or infestation of other fields. There is also the possibility of spreading weed seed to other properties.

It has been shown that seed from weeds (Piggin 1978, Wallander *et al.* 1995, Olson *et al.* 1997) and pasture species (Edward *et al.* 1998) can pass through sheep and remain viable. Piggin (1978) suggested that, despite all germinable seed being passed within three days, sheep are most likely responsible for the spread of Paterson's curse (*Echium plantagineum* L.) across Australia. Control of volunteer crop species is also an aspect of weed control that needs to be considered. Whilst work has been done on the intake or nutritive qualities of crop seeds (Curtis and Mavrantonis 1990), no reports detail the viability of any excreted crop seeds.

Rate of passage

Cattle have been identified as a high risk for spreading prickly acacia (*Acacia nilotica* L.) due to seed dispersal after ingestion (Tiver *et al.* 2001). To minimize the spread of prickly acacia, they recommend that livestock that come from infested properties are quarantined for six days until seeds have passed through the digestive tract. Further, management strategies should control cattle movements between paddocks during periods when cattle are ingesting pods and seeds.

Similarly, it can take up to five days for all annual ryegrass seed to pass through the digestive tract of sheep, which is in line with findings for other weed species (Table 1). There is also agreement within the literature that seeds can pass through the digestive tract of sheep and cattle within 24 hours. Therefore, any management strategies for controlling the movement of weed seeds by livestock must be

Table 1. Reported rates of seed passage, seed recovery and germination of selected seeds ingested by sheep and cattle.

Species	Retention time (days)		Per cent recovered		Per cent germination		
	sheep	cattle	sheep	cattle	sheep	cattle	Source
Prickly acacia		6					Tiver *et al.* 2001
Giant Parramatta grass		4–7		6		19	Andrews 1995
Chilean needle grass		4		2–6		<50	Gardener *et al.* 2003
Giant rats tail grass		4		41		79	Bray *et al.* 1998
Annual ryegrass	4	4	11	33	21–40	24–40	Stanton *et al.* 2002
Pasture species[A]	2–3	2–3	11	48	0–60	0–60	Simao Neto *et al.* 1987
Serradella	2–5		<10		–		Edward *et al.* 1998
Paterson's Curse	3		–		1–2		Piggin 1978
Spotted knapweed	5		4		0–26		Wallander *et al.* 1995
Leafy spurge	–		4		5–24		Olson *et al.* 1997

[A] Stylo, glycine, clover species, carpet grass and signal grass.

implemented early after ingestion and remain in place for up to a week to account for any seeds that are excreted.

Per cent excretion

Cattle on restricted intakes can excrete up to 8%, 40% and 48% of oat, barley and wheat grain respectively (Toland 1976). Comparable rates of excretion have been reported for a range of weed species (Table 1). Significantly, a lower percentage of ingested seed is reported to be excreted by sheep, with this difference suggested as being a result of the extent to which the two animals chew the grains (Waldo 1973).

The viability of the recovered seeds as reported by these authors was highly variable, and this may also be a result of several factors.

The maturity of the ingested seed may contribute to the amount excreted. Olson and Wallander (2002) reported that less leafy spurge seed (*Euphorbia esula* L.) seed at the soft dough stage was excreted and remained viable compared to hard dough or mature seed. Other factors such as quantities of seed ingested, seed characteristics, diet quality, the species and age of animals used, length of time in the rumen and basal diet have also been suggested as contributing to the observed level of viability of excreted seeds (Blackshaw and Rode 1991). It would appear, however, that viability of seeds is significantly reduced by passage through animals.

Seed size and shape

The size of ingested seed may influence the fate of seed in the intestine of livestock. When using spheres of various densities ranging in size from 3.2 mm to 12.7 mm fed to Holstein heifers, Ehle and Stern (1986) found that particle density has a greater effect on intestinal passage than particle size, and it was only at low particle density that smaller particles passed through heifers more readily than larger particles. The medium density spheres (1.34 g mL^{-1}) were also observed to pass through cattle the quickest and in the highest numbers.

When feeding seed from a range of pasture species to sheep and cattle, Simao Neto *et al.* (1987) observed that more short seeds were excreted by sheep compared to long seeds. However, seed shape did not influence the amount of seed excreted by cattle, although larger seeds tended to have a slower rate of passage.

Seed coat thickness

Tiffney (2004) suggests that endozoochorous seed dispersal requires a seed coat that provides the embryo with protection during passage through the gut, yet does not greatly inhibit subsequent germination.

There are significant morphological differences between yellow and brown brassica seeds (Vaughan 1959, Stringam *et al.* 1974), with yellow seeds having thinner seed coats with higher levels of oil and protein when compared to brown seeds. When canola seed hulls are fed to pigs, Bell and Shires (1982) found that the yellow seed hulls were more digestible than brown hulls. The thinner, more digestible nature of yellow seed hulls would indicate that lighter coloured seed would be less likely to pass through livestock and remain viable compared to darker coloured seed. While St John *et al.* (1987) have reported that canola seed hulls are less digestible than the seed embryo, and therefore potentially protect the embryo during passage though the digestive tract, only a low percentage of dark coloured canola seed ingested by sheep is excreted whole (Stanton *et al.* 2003).

Seed quality

The oil content of the seeds may also influence rate of passage through the digestive tract, and therefore the viability of excreted seed. Increasing levels of oils and fats in the diet of lambs (Petit *et al.* 1997) and cattle (Hussein *et al.* 1996) can decrease the DM digestibility in both animals. Therefore, as oil in the diet increases, through either increased oil content of the seeds or increased intake of seeds, some disruption to normal intestinal function could be expected. This can lead to lower digestibility and faster rates of passage, which may tend to increase the numbers and viability of excreted seed. However, from a livestock management perspective, this may also reduce the length of time taken for all seeds to be excreted after ingestion. Further, while the quality of the seeds ingested can influence the rate of passage and the level of germinability of excreted seed, the quantity of seed in the diet is likely to be more influential.

Summary

The potential for seed dispersal by livestock has implications for integrated weed management. The practice of utilizing sheep and/or cattle to reduce additions to the seedbank and hence restrict the build up of weeds needs refinement. Sheep are more effective than cattle in reducing the amount of germinable seed and should be used in preference to cattle. Further, the time taken for passage of seed through the digestive system could provide a mechanism for spread of weeds beyond the field. It is inevitable that there will be spread within the field where the seed is consumed. However, there needs to be a period of several days following consumption to ensure clean-out of the digestive tract before animals are moved to new areas to minimize the risk of spread.

The fate of ingested seeds is becoming more important as herbicide tolerant crops, such as triazine tolerant and imidazolinone tolerant varieties of wheat and canola, are introduced or herbicide resistant weeds become more prevalent. Spread of seeds can be avoided by the use of appropriate animal husbandry practices. Restricting livestock to a holding area for seven days would ensure that they had passed all viable seeds before being moved away from the field. This would be more critical in the case of stock that had only been exposed to the seed source for a short period of time and therefore potentially had a higher level of seed in their diet. This management technique should be seen as an essential part of any effective integrated weed management strategy. It would have the advantage of ensuring that any seeds are not spread away from the source field, as most seeds appear to have similar retention times in the intestine. Newly purchased livestock should also be held in yards for a similar time period for the reason of ensuring that no undesired plants are introduced onto the property.

References

Andrews, T.S. (1995). Dispersal of seeds of giant *Sporobolus* spp. after ingestion by grazing cattle. *Australian Journal of Experimental Agriculture* 35, 353-6.

Bell, J.M. and Shires, A. (1982). Composition and digestibility by pigs of hull fractions from rapeseed cultivars with yellow or brown seed coats. *Canadian Journal of Animal Science* 62, 557-65.

Blackshaw, R.E. and Rode, L.M. (1991). Effect of ensiling and rumen digestion by cattle on weed seed viability. *Weed Science* 39, 104-8.

Bray, A.G., Cahill, L., Paton, C.J., Bahnisch, L. and Silcock, R. (1998). Can cattle spread giant rat's tail grass seed (*Sporobolus pyramidalis*) in their faeces? Proceedings of 9th Australian Agronomy Conference, Wagga Wagga, pp. 575-8.

Couvreur, M., Verheyen, K. and Hermy, M. (2005). Experimental assessment of plant seed retention times in fur of cattle and horse. *Flora 200* 2, 136-47

Curtis, K.M.S. and Mavrantonis, B. (1990). Intake of lupin seed and pasture by sheep fed lupins while grazing dry pasture. *Proceedings of the Australian Society of Animal Production* 18, 180-3.

Declerckfloate, R. (1997). Cattle as dispersers of hound's-tongue on rangeland in southeastern British Columbia. *Journal of Range Management* 50, 239-43.

Edward, A.Y., Ewing, M.A. and Revell, C.K. (1998). Fate of serradella, medic and biserrula seeds in pods ingested by sheep. Proceedings of 9th Australian Agronomy Conference. Wagga Wagga, pp. 199-202.

Ehle, F.R. and Stern, M.D. (1986). Influence of particle size and density on particulate passage through alimentary tract of Holstein heifers. *Journal of Dairy Science* 69, 564-8.

Fischer, S.F., Poschlod, P. and Beinlich, B. (1996). Experimental studies on the dispersal of plants and animals on sheep in calcareous grasslands. *Journal of Applied Ecology* 33, 1206-22.

Gardener, C.J., McIvor, J.G. and Jansen, A. (1993). Survival of seeds of tropical grassland species subjected to bovine digestion. *Journal of Applied Ecology* 30, 75-85.

Gardener, M.R., Whalley, R.D.B. and Sindel, B.M. (2003). Ecology of *Nassella neesiana*, Chilean needle grass, in pastures on the Northern Tablelands of New South Wales. I. Seed production and dispersal *Australian Journal of Agricultural Research* 54, 613-19

Hughes, L., Dunlop, M., French, K., Leishman, M.R., Rice, B., Rodgerson, L. and Westoby, M. (1994). Predicting dispersal spectra – a minimal set of hypotheses based on plant attributes. *Journal of Ecology* 82, 933-50.

Hussein, H.S., Merchen, N.R. and Fahey, G.C. (1996). Effects of forage percentage and canola seed on ruminal protein metabolism and duodenal flows of amino acids in steers. *Journal of Dairy Science* 79, 98-104.

Olson, B.E. and Wallander, R.T. (2002). Does ruminal retention time affect leafy spurge seed of varying maturity? *Journal of Range Management* 55, 65-9.

Olson, B.E., Wallander, R.T. and Kott, R.W. (1997). Recovery of leafy spurge seed from sheep. *Journal of Range Management* 50, 10-15.

Petit, H.V., Rioux, R., Doliveira, P.S. and Doprado, I.N. (1997). Performance of growing lambs fed grass silage with raw or extruded soybean or canola seeds. *Canadian Journal of Animal Science* 77, 455-63.

Piggin, C.M. (1978). Dispersal of *Echium plantagineum* L. by sheep. *Weed Research* 18, 155-60.

Romermann, C., Tackenberg, O. and Poschlod, P. (2005). How to predict attachment potential of seeds to sheep and cattle coat from simple morphological seed traits. *Oikos* 110, 219-30.

Simao Neto, M., Jones, R.M. and Ratcliff, D. (1987). Recovery of pasture seed ingested by ruminants. I. Seed of six tropical pasture species fed to cattle, sheep and goats. *Australian Journal of Experimental Agriculture* 27, 239-46.

Sorensen, A.E. (1986). Seed dispersal by adhesion. *Annual Review of Ecology and Systematics* 17, 443-63

St John, L.C., Young, C.R., Knabe, D.A., Thompson, L.D., Schelling, G.T., Grundy, S.M. and Smith, S.B. (1987). Fatty acid profiles and sensory and carcass traits of tissues from steers and swine fed an elevated monounsaturated fat diet. *Journal of Animal Science* 64, 1441-7.

Stanton, R., Piltz, J., Pratley, J., Kaiser, A., Hudson, D. and Dill, G. (2002). Annual ryegrass (*Lolium rigidum*) seed survival and digestibility in cattle and sheep. *Australian Journal of Experimental Agriculture* 42, 111-15.

Stanton R., Pratley J. and Hudson D. (2003). Sheep are potential vectors for the spread of canola (*Brassica napus*) seed. *Australian Journal of Experimental Agriculture* 43, 1-4.

Stringam, G.R., McGregor, D.I. and Pawlowski, S.H. (1974). Chemical and morphological characteristics associated with seedcoat colour in rapeseed. Proceedings of 4th International Rapeseed Conference, Giessen, pp. 99-108.

Tiffney, B.H. (2005). Vertebrate dispersal of seed plants through time. *Annual Review of Ecology, Evolution, and Systematics* 35, 1-29

Tiffney, B.H. and Mazer, S.J. (1995). Angiosperm growth habit, dispersal and diversification reconsidered. *Evolutionary Ecology* 9, 93-117

Tiver, F., Nicholas, M., Kriticos, D. and Brown, J.R. (2001). Low density of prickly acacia under sheep grazing in Queensland. *Journal of Range Management,* 54, 382-9.

Toland, P.C. (1976). The digestibility of wheat, barley or oat grain fed either whole or rolled at restricted levels with hay to steers. *Australian Journal of Experiment Agriculture* 16, 71-5.

Vaughan, J.G. (1959). The testa of some Brassica seeds of oriental origin. *Phytomorphology* 9, 107-10.

Waldo, D.R. (1973). Extent and partition of cereal grain starch digestion in ruminants. *Journal of Animal Sciences* 37, 1062-74.

Wallander, R.T., Olson, B.E. and Lacey, J.R. (1995). Spotted knapweed seed viability after passing through sheep and mule deer. *Journal of Range Management* 48, 145-9.