DRY SEASON CROP RESIDUE MANAGEMENT USING ORGANIC LIVESTOCK REPELLENTS UNDER CONSERVATION AGRICULTURE IN ZIMBABWE

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Abstract

The maintenance of a permanent organic soil cover using crop residues under conservation agriculture in Zimbabwe is limited by the competing use of residues as livestock feed. To help address this challenge, this study evaluated the effectiveness of repellents as a management option for protecting crop residues from grazing cattle during dry seasons. Initial on-station trials at Domboshawa, Zimbabwe, in 2009 demonstrated the potential of cow dung, goat droppings, chilli, dry tobacco dust and soaked tobacco as possible cattle repellents and optimum application rates of 3000, 500, 400, 1200 and 300 kg/ha, respectively, were established. These were then tested on farmers' fields at Hereford, an area with high biomass production and Madziwa with low biomass production. It became apparent that at Hereford, after 5 weeks, cow dung, soaked tobacco and tobacco scrap treatments, retained significantly ($P < 0.05$) higher residue amounts of 66.4, 64.5 and 60.7% respectively, compared to the untreated control with 49.7%. On the other hand, at Madziwa, all residues were consumed within three days, irrespective of treatment. The study thus demonstrated that these repellents can be used to protect crop residues from livestock grazing in areas with high biomass production offering alternative feed but ineffective in areas with acute shortage of alternative feed. The study opens a new avenue for crop residue control in crop-livestock systems.

Key words: maize residues, moisture conservation, non-consumption period.

Introduction

The conservation agriculture (CA) principle of maintaining a permanent soil cover has been found to increase soil water retention (Nyagumbo, 2002; Reicosky, 2008) and increase soil fertility (Chivenge *et al.* 2007). Soil water retention can be increased by mulching as a result of reduced run-off, hence increasing infiltration and reducing the soil water evaporation (Nyagumbo 2002, Thanachit *et al.* 2011). Despite the benefits of mulching, adoption of this principle has largely remained low (Chiputwa *et al.* 2010, Twomlow *et al.* 2008). The low adoption of this principle has been attributed to high labour demands arising from the need to carry maize residues from fields at harvest and returning them at the beginning of the next season and the competing uses of residues as soil cover and as livestock feed.

When animals graze crop residues, more nutrients are removed than returned via cow dung (Powell and Williams 1993) since manure and urine voidings are distributed unevenly in fields during grazing. In contrast, fields regularly receiving manure applications from cattle kraals benefit from increase in soil pH, infiltration rate, water holding capacity and decreased bulk densities (Murwira 1993). Vulnerable groups of farmers without livestock thus find themselves struggling to maintain or improve the fertility status of their soils, resulting in reduced crop productivity. In Zimbabwe, crop yield for cattle owners was 3-5 t grain yr^{-1} $farm^{-1}$ whilst the non-cattle owners had less than 1 t grain yr^{-1} $farm^{-1}$ due to poor soil quality and low manure use by non-cattle owners (Rufino *et al.* 2010). A reduction in field surface mulch by 30-46% as a result of dry winter season grazing by livestock, leaving less than 0.2 t/ha of biomass, has been recorded in Zimbabwe (Mtambanengwe and Mapfumo 2005). This is mainly due to communal livestock grazing in arable areas during the winter season in most smallholder farming areas. Farmers practising CA thus face a critical problem to ensure enough residues remain in the field to meet the threshold of mulching at the start of the rain season (Mazvimavi and Twomlow 2008). Innovative ways of managing crop residues during non-cropping seasons are thus required to ensure that farmers embarking on CA can do so without being disadvantaged by cattle.

Generally, fencing was identified as the most common option of residue protection practiced by farmers (Nyagumbo *et al.* 2009). However, adoption has been poor amongst smallholder farmers due to prohibitive costs of fencing materials (Wall 2009). Alternatively, farmers may use live fencing to protect residues but the length of time required for establishment of the live fences remains a challenge. One approach to address this problem could be through the use of organic livestock repellents applied to the crop residues. Repellents are substances designed to irritate a specific animal or type of animal such that the targeted animal will avoid the protected objects or area (Osko 1993). Some repellents (such as mixture of *Allium sativum* (garlic), *Allium cepa* (onions) and *Capsicum oleoresin* (chilli*))* successfully deterred animals like deers from grazing gardens (Deer-Departed LLC 2007) while elephants were repelled from fields by chilli spray (Osborn 2002). Several specific chemicals in cattle faeces were also found to be involved in inhibiting cattle from ingesting grass near cattle faeces (Dohi *et al.* 1999). Such an approach could thus provide an option for protecting crop residues and hence the need to test whether substances such as chilli, cow dung and goat droppings can also exhibit the same repelling characteristics to cattle when they are sprayed on crop residues during the dry season.

This study thus sought to investigate and establish the feasibility of such repellents to control the dry season grazing of crop residues by livestock in CA systems. The research hypothesised that effective locally available organic substances exist that can be used as repellents to grazing of crop residues by cattle under CA, during dry winter season. The objectives of this study were to identify, screen and test locally available organic resources that can be used as repellents to grazing of maize residues by cattle during dry seasons.

Materials and Methods

Site description

Initial work to screen organic repellents to be used as residue management options to grazing of crop residues by livestock was carried out at Domboshawa Training Centre (DTC) (17° 35' S; 31° 10' E) located about 33 km North of Harare, Zimbabwe. DTC is in agro ecological zone IIa (Vincent and Thomas 1960) and experiences a subtropical climate with an annual rainfall range of 750 – 1000 mm and a mean annual temperature of 15-20 °C. Intensive crop farming is the recommended farming activity (Vincent and Thomas 1960). The soils are shallow to moderately deep, gleyic granite derived sands generally classified as Paraferralitic soils (Nyamapfene 1991). DTC is a centre for agricultural training and research.

Subsequent on-farm studies on screened repellents were carried out in Bindura from August –September 2010 at Hereford Farm (17° 25' S; 31° 26' E) and Madziwa communal area (16° 55' S; 31° 32' E). Hereford farm is in agro ecological zone IIa, thus receives same climatic conditions as for DTC but has red clays soils. Madziwa in agro ecological zone IIb, (receiving less than 750 mm annual rainfall) is a communal area with depleted sandy soils. Maize is the major cereal crop grown in both Domboshawa and Bindura, hence maize stover was used for the experiment. The livestock used for both on station and on farm was cattle. On station, the cattle were driven into the field and removed at sunset, whilst on farm, the cattle grazed communally and in some instances spent the night in the field.

Experimental design and treatments

Potential repellents were identified through consultations with farmers, livestock experts and other key informants by asking for names of local plants or materials that were shunned by livestock, but were known to be non poisonous to the livestock. Farmers consulted were in areas where CA was already being implemented but with challenges of cattle grazing the crop residues in the dry season. Informal discussions were made with CA practitioners, livestock experts and key informants for the possible repellents. The names of possible repellents were suggested by 1) farmers in Kadoma, Chikombedzi, Domboshawa and Bindura; 2) livestock experts at the University of Zimbabwe (Animal Science and Veterinary Science departments) and 3) key informants, mainly extension workers in the same areas as farmers. The eight potential resources/substances suggested to function as repellents were: garlic (*Allium sativum*); onions (*Allium cepa*); mixture of garlic and onion; cow dung; goat droppings; cow dung mixed with goat droppings; chilli (*Capsicum* spp.); tobacco (*Nicotiana* spp.); crotalaria (*Crotalaria grahamiana*) and *mutovoti* plant (*Spirostachys africana*). These resources or substances were then screened using a completely randomised block design (CRBD) with 3 replicates at DTC.

Each plot measuring 5 m x 5 m received 10 kg of maize residues (equivalent to a residue application rate of 4 t/ha) at the beginning of the experiment. The dry residues were initially weighed using a digital hanging scale and then evenly applied and spread by hands on the surface of marked plots, lying across the field slope. For the repellents that were soaked, the pure form of repellents was put in a bucket and the desired amount of water was added. The mixture was then stirred thoroughly until a perfect mixture was made and was left to soak overnight. To apply the repellents to the maize stover, a sweeping broom was used to spray and spread wet chilli on the residues while hands were used for the other soaked ones. Dry repellents were manually broadcasted onto the residues uniformly until the desired amount was finished on each plot. The residues remaining in the field after grazing were weighed. The effectiveness of these substances suggested as potential repellents was determined by measuring the period taken to consume 50% of sprayed residues after releasing cattle. A substance was considered as a potentially effective repellent if it (a) repelled livestock from grazing maize stover for a period of at least three weeks and (b) prevented more than 50% of the maize stover being removed. Estimation was used to determine that 50% was used during the screening stage. This initial screening was carried out using a medium application rate of each repellent (Table 1). We assumed that the drying rates of residues was similar since all plots started with the same residue application rate.

Further tests were carried out at DTC on four screened repellents in September - November 2009, to determine their optimum application rate. For the best four screened resources (cow dung, goat droppings, chilli and tobacco), a split plot design was laid out in three randomized blocks to determine their optimum application rate. The four repellents were assigned at random to the main plots within each block at three application rates (Table 1) as subplots.

A control where nothing was sprayed was also assigned at random to the main plot in each block. The efficacy of repellents (compared to the control) was indicated by the non-consumption period of residues by livestock and the amount of residues left after a given period. The repellent's application rate (out of the three in Table 1) with the least consumed residues was considered as the optimum application rate. The optimum application rates obtained from the DTC trials were then tested on communally grazed areas in Bindura district.

Table 1. The three application rates tested at the Domboshawa Training Centre for each repellent to obtain the optimum level.

Repellent	Concentration	Weight of dry repellent (kg)	Concentration (kg/l)	Application rate (kg/ha)
Chilli powder	Low	0.25		100
	Medium	0.5		200
	High	1		400
Soaked cow dung	Low	7.5	1.5	3000
	Medium	10	2	4000
	High	12.5	2.5	5000
Tobacco scrap	Low	0.75		300
	Medium	1.5		600
	High	3		1200
Soaked goat droppings	Low	1.25	0.17	500
	Medium	2.5	0.33	1000
	High	3.75	0.5	1500
Soaked chilli	Low	0.25	0.03	100
	Medium	0.5	0.05	200
	High	1	0.1	400
Soaked tobacco	Low	0.75	0.05	300
	Medium	1.5	0.1	600
	High	3	0.2	1200
Control		0	0	0

On-farm trials were set up in Madziwa and Hereford to determine the efficiency of the optimum application rates obtained at DTC on communally grazed areas. At Hereford farm and Madziwa, efficiency was based on non-consumption days and reduction in residue amount over time using CRBD layouts (Figure 1).

ST	SC	C/dung	CP	GD	TS
C/dung	CP	TS	SC	ST	GD
CP	ST	GD	TS	C/dung	SC

Figure 1. Field layout used at on farm experiments in Bindura (Madziwa and Hereford). Notes: The plots are 5m × 5m and the paths are 2m × 2m. ST =soaked tobacco, SC = soaked chilli, C/dung = cow dung, CP = chilli powder, GD = goat droppings, TS = tobacco scrap.

Results

From observations and informal discussions with local people, it became apparent that in Bindura, cattle were left to graze freely on pastures and arable areas during the dry season compared to DTC where fencing controlled which areas were grazed. Hereford farm by virtue of being in a high potential region, tended to produce more crop residues and the conditions there provided for alternative animal feed in the form of grasses and shrubs persisting during the dry season and thus retained a considerable amount of crop residues in the field up to the beginning of the next cropping season after cattle grazing. In contrast, Madziwa had much lower annual biomass yield and all the crop residues in the fields are consumed by July with little alternative grass and shrubs available for livestock grazing. Farmers usually collect and stock/pile crop residues from their fields and store them as dry season animal feed.

Identification and screening of potential repellents

Cow dung, goat droppings, chilli and tobacco were found to be effective repellents to grazing of crop residues by livestock at DTC (Table 2) as greater than 50% of initial residues were left after cattle consumption for up to 21 days.

Table 2. Number of days when more than 50% of initial maize stover was consumed after organic repellents were used to control cattle at Domboshawa in 2009. The medium application rates of each repellent in Table 1 were tested

Repellent	Days
Soaked garlic	5
Soaked onions	5
mixture of soaked garlic and onion	4
Soaked cow dung	up to 21
Soaked goat droppings	up to 21
Mutovoti plant	6
Chilli (both powder and soaked)	up to 21
Tobacco (both soaked and scrap)	up to 21
Control	4
Soaked crotalaria	4

Results of the best four resources at different concentrations proved that soaked cow dung, tobacco and goat droppings were more efficient at low concentrations (Figure 2). Generally, the low concentration (equivalent to 3 t/ha) of cow dung was more effective compared to others. The optimum application rates (Table 3) obtained at DTC were then used on on-farm trials in Bindura district.

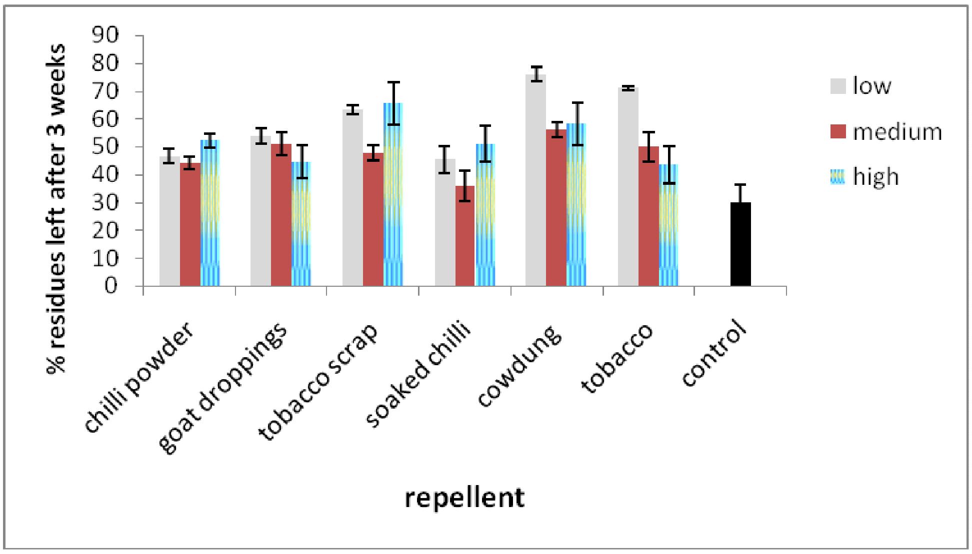

Figure 2: Efficacy of different application rates of each repellent at the Domboshawa Training Centre in 2009. Note: Low, medium and high, represents the three application rates for each repellent. Error bars (standard error of means) were used to compare means of each repellent at the three concentrations levels and not across repellents.

Table 3. The optimum application rates of repellents from Domboshawa that were tested in Bindura (Hereford and Madziwa communities).

Repellent	Application rates (kg/ha)
Soaked cow dung	3,000
Soaked goat droppings	500
Chilli (soaked and powder)	400
Tobacco scrap	1,200
Soaked tobacco	300

Efficacy of repellents

Results collected from Hereford farm showed that cow dung and tobacco (both soaked and scrap) were effective to repel the livestock for a longer time of up to 5 weeks. There were no significant repelling effects arising from chilli (both soaked and powder) and goat droppings compared to the control (Figure 3).

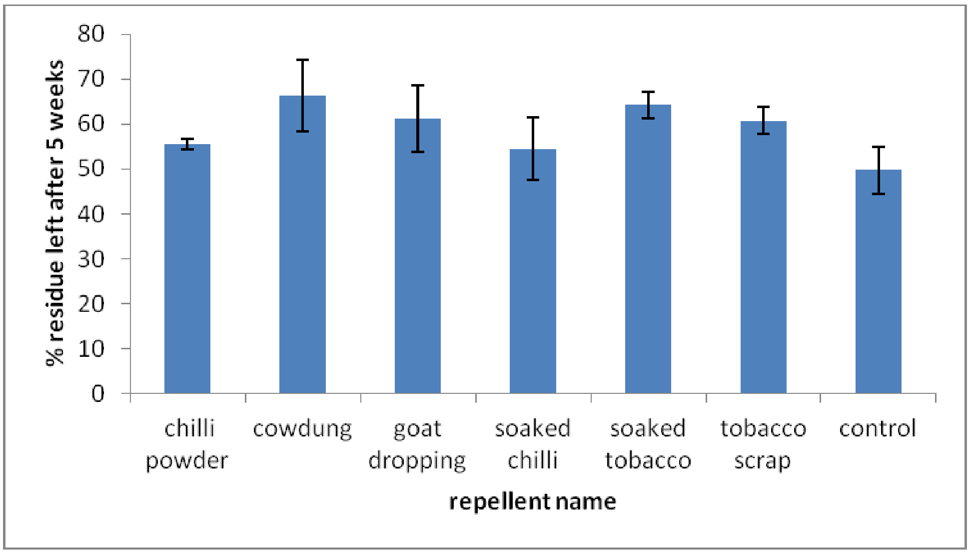

Figure 3: Efficacy of repellents at Hereford farm in 2010 in terms of percent residues remaining after 5 weeks. Error bars = standard error of means.

In terms of the non-consumption period, the control was eaten the very day the experiment was set up (day 0) whilst cow dung and soaked tobacco were the last to be eaten (Table 4). Despite the choking effect, tobacco and chilli powder were easily blown away by wind to underneath the residues or away from residues, hence residues treated with them were eaten earlier than soaked repellents (Table 4).

Table 4. Efficacy of repellents in terms of non-consumption period at Hereford farm in 2010.

Name of repellent	Non-consumption period (days after application)
Chilli powder	4
Soaked chilli	7
Soaked tobacco	10
Tobacco scraps	6
Cow dung	10
Goat droppings	7
Control	0

In Madziwa, all the residues were eaten up within three days of setting up the trial. Thus, no data on weights of remaining residues was collected after that period. From observations in Madziwa, livestock consumed the residues preferentially in the order: control > goat droppings > dry tobacco > wet chilli > chilli powder > wet tobacco > cow dung.

Discussion

Effectiveness of repellents to deter grazing livestock

The screened repellents (tobacco, chilli, cow dung and goat droppings) used in this study reduced grazing intensity in Hereford but did not eliminate grazing entirely, although repellents should be designed to be so irritating to a specific animal or type of animal that the targeted animal will avoid the protected objects or area (Osko 1993). A study in Zimbabwe by Mtambanengwe *et al.* (2010) showed that fields that are unprotected from livestock grazing during dry season periods had residue amounts declining by up to 93% over the 5-6 months dry season compared to less than 25% in protected/fenced fields. However, in this study, use of repellents resulted in a decline of initial crop residues by 36-45% compared to the control with a 50% decline at Hereford. Hence, repellents provided a better retention of crop residues during winter than unfenced fields but were less effective than exclusion of grazing by fencing crop residues. The repellents with a disagreeable odour and choking effect (chilli, cow dung and tobacco) tended to be more effective in controlling grazing than the ones that repelled by taste (onions, garlic, mutovoti plant, and *Grahamiana* spp). This finding is supported by Hill (2002) who also found out that substances that repel by taste are less effective compared to those that repel by a disagreeable odour when deterring elephants from crop fields.

From the three application rates tested at DTC for each repellent (Table 1), soaked cow dung, tobacco and goat droppings proved to be more efficient when the solution is more dilute (3000, 300 and 500 kg/ha respectively) compared to a highly viscous slurry (5000, 1200 and 1500 kg/ha respectively), whilst wet chilli was more efficient at high concentration 400 kg/ha compared to 100 kg/ha. The higher efficacy of lower concentrations could be due to the fact that the residues would absorb more of the solution thus adding a bad taste on the residues for a longer time. The repellents could then be deterring livestock through both the smell and taste effect. With respect to chilli, Osborn (2002) reported that a naturally occurring chemical in chilli peppers, called capsaicin causes a heat sensation when it reaches nerve receptors. This heat deters mammals from grazing on chilli peppers or on crops that have been sprayed with chilli pepper extract. This could then support the efficacy of chilli to deter cattle from treated crop residues at DTC and Hereford.

Although the repellents proved to be more efficient via the smelling and choking effect as opposed to taste, chilli and tobacco scrap which had the choking effect were easily blown way from the residues by wind and could drop off the residues as the cattle trampled on the residues during grazing. For soaked chilli, cow dung and goat droppings, their stains tend to disappear from residues after sometime, where after, their efficacy was now due to taste and livestock would bite and spit. This supports findings by Dohi *et al.*, (1999) that taste repellents only work after the animal has taken a bite out of the plant.

The difference in results obtained at Hereford and Madziwa confirms that what an animal eats largely depends on available food resources (Osko 1993, Hill 2002). The repellents proved to be effective at Hereford where there is alternative feed, whilst in Madziwa where there is nothing except the treated residues, they were not effective. Cow dung was more effective in Hereford than other repellents thus supporting Marten (1978) who reported refusal of dairy cattle to graze on brome (*Bromus* spp) growing over areas dressed with cow, sheep and turkey manure and accepted the same vegetation when it was harvested and offered as fresh fodder. We think that as long as farmers in areas like Hereford have realised the benefits of CA and its principles, they are prepared to conserve the maize stover provided the repellents are accessible and available since those who afford fencing are already doing so.

Challenges in using repellents

In smallholder farming areas of Zimbabwe where grazing is communal in croplands during the dry season (Rufino 2010), the use of repellents might raise social conflicts on ownership of repellents and where individual farmers do not have exclusive rights to the residues on their land, any attempts to conserve the residues can lead to confrontation (Wall 2009). Information sharing and knowledge development in such rural areas could then help to resolve these issues since if farmers carry, store and then return residues to their fields, no conflicts are raised. In Zimbabwe, Wall (2009) reported success with CA farmers through support from a local government councillor who facilitated a by-law barring communal grazing of fields in winter following CA demonstrations implemented in Shamva. The practice of communal grazing has been found to result in net nutrient transfer from fields owned by non-cattle owners to those of cattle owners through regular manure applications in the fields of the latter (Mtambanengwe 2006). Local studies in the past have also shown the benefit of cattle manure and goat droppings (Masikati 2006) to replenish soil fertility. Thus, communal grazing occurs at the expense of the poorer farmers who lose their residues to cattle owners. The use of livestock repellents (in conditions where feasible) could thus prove to be a useful measure to protect residues in CA fields of non-livestock owners, thereby helping to curb this unperceived theft of nutrients by livestock owners. The findings of this study could thus open a new avenue for livestock management in CA systems.

Most repellents lasted for at most three to five weeks and thus need re-application after a certain period to deter grazing livestock throughout the long 5-6 month dry season. The need for reapplication may be influenced by factors such as rainfall, atmospheric temperature and appetite of the livestock, which affect the efficacy of the repellent. The timing of the application is also important since there is need for dry weather for about 48 hours when one applies the repellent. Apart from these challenges, livestock can become adapted to the repellents and end up grazing protected/sprayed residues. It is admitted that the rates used here are too high, hence the study provides a benchmark to effective control rates and so further studies should be conducted to refine or extract the active repelling ingredients that can be applied at much lower rates. More factors could be explored, which might reduce the required repellent amounts such as by increasing or reducing the period of soaking repellents. However, since most farmers have already seen the importance of mulching and thus were carrying stover, stacking it and bringing it back at the beginning of the next season, while others were fencing, we believe that the task of applying such repellents should be borne by the individual owners managing their fields and cannot be a communal effort since traditionally field activities are managed individually.

While unlikely, side effects might arise if animals are forced to eat excessive amounts of the repellents. Unfortunately this aspect could not be substantiated in this study. For example, excessive capsaicin (from chilli) has been known to temporarily irritate mucus membranes in the gastrointestinal tract of an animal (Mozsik *et al.* 2009), whilst nicotine in tobacco is known to causes relaxation of muscles in the gastrointestinal tract (Irie *et al.* 1991). Literature also suggests the consumption of animal excreta such as cowdung and goat droppings might cause the spread of internal parasites such as *Ooperia* and *Trichostronglus* species in the animal (Fontenot and Webb 1975). This probably warrants further studying to determine the amounts of these active ingredients in each repellent to prevent animal poisoning, particularly in situations where the animals are forced to eat the repellent because of acute shortages of alternative feed. Unfortunately this study did not establish the extent of these potentially harmful effects on livestock.

Limitations of the study

The study results were obtained from small sized plots, and they might differ if a bigger area was used, since untreated feed would be far away. Furthermore, some of the required repellents' effective application rates were rather high and thus may be difficult to acquire if resources are to be borrowed or bought, e.g. chilli in contrast to cow dung which can be readily available.

Conclusion

Cow dung and tobacco dust proved to be the promising repellent options that could be used to keep livestock away from residues during the winter, but their efficiency largely depends on the availability of alternative feed. The study demonstrates that these repellents can be used to protect crop residues from livestock grazing in areas with high biomass production offering alternative feed but may be ineffective in areas with acute shortage of alternative feed. Repellents' effectiveness was generally found to be temporary and short lived as the residues were eaten in time, suggesting the need for repeated applications at least every 3 weeks. The study opens a new avenue and approach for residue management in CA systems that could potentially address the livestock competition challenges experienced in crop-livestock systems, particularly if the repellents' active ingredients are extracted and repackaged in more user-friendly formats such as sachets, enabling easy application through knapsack spraying.

Besides the need for repackaging the identified effective repellents, there is need for further studies to quantify the potential side effects of these repellents on animal health.

Acknowledgements

The authors of this paper acknowledge the funding received from the Regional Universities Forum (RUFORUM) and the International Maize and Wheat Improvement Center (CIMMYT) for transport support to the on farm field sites used during the study.

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