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Screening Green Manure Cover Crops for their Allelopathic Effects on Some Important Weeds Found in Zimbabwe

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Abstract

Weed control is a serious problem in smallholder conservation agriculture farming areas in Zimbabwe. Green Manure Cover Crops (GMCCs), which improve soil fertility and reduce weeds through allelopathy, are likely to reduce the cost of weed control in these areas. A laboratory study was conducted at the University of Zimbabwe to investigate the effect of extracts of eleven GMCCs on the germination percentage, radicle and plumule length of *Bidens pilosa*, *Eleusine indica* and *Pennisatum glaucum* (pearl millet). A green house experiment was also done to determine the allelopathic potential of these GMCC extracts applied as soil incorporated residues on the emergence and dry matter production of *E. indica, B. pilosa* and *Acanthospermum hispidum*. GMCC extracts significantly reduced germination, radicle and plumule length of *Pennisatum glaucum* ($P < 0.05$) except for *Crotalaria grahamiana* and *Raphanus sativas* which had no effect on germination of Pearl millet. The emergence and dry matter of *B. pilosa*, *E. indica* and *A. hispidum* were significantly reduced by these legumes ($P < 0.05$) with the exception of common vetch (*Vicia sativa*) which stimulated the emergence of *A. hispidum*. Most of the legumes that were used in this study have allelopathic effects on *B. pilosa, E. indica* and *A. hispidum*.

Keywords: Allelopathy, Green manure cover crops, Conservation agriculture

Introduction

Conservation Agriculture (CA) is a broad concept involving minimal soil disturbance, maintenance of a permanent soil cover and a rational use of crop rotations (FAO, 2007; Harrington and Erenstein, 2005; Hobbs, 2007). Minimum soil disturbance under CA is being achieved by the use of planting basins and the use of implements such a as the jab planter and the direct seeder, which are used to plant into untilled soil, and also through the use of ripper tines that only open a furrow where the seed is placed. Permanent soil cover is being achieved by retaining crop residues from the previous season and also through relay intercropping with green manure cover crops (GMCCs). GMCCs, mostly legumes, are crops that are grown as soon as possible after harvest of the previous crop (Derpsch, 2008), alternatively leguminous crops such as sunnhemp (*Crotalaria juncea* L) are planted in between maize as live mulch. In some instances, the new crop may be drilled directly into the GMCC. There is enough scientific evidence that no-tillage without permanent soil cover results in poor yields (Ashburner, 1984; Wall, 1999; Sayre *et al*., 2006). Permanent soil cover with a thick layer of mulch has been a key factor for success in CA systems in South America. Derpsch (2008) reported that a farmer should aim at having at least six and if possible more than 10 tonne per hectare of dry matter from crop residues and or

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green manure cover crops every year. This way, a farmer can achieve good weed suppression, positive effects of mulch on soil moisture and soil temperature, and improve the chemical, physical and biological soil properties.

The shift from tillage systems that include extensive annual soil disturbance to CA systems that minimize soil disturbance causes major changes in weed population dynamics. These changes often reduce the effectiveness of weed control practices. While results have varied among experiments, some general trends in weed population dynamics have arisen as tillage is reduced. These include increased populations of perennial, summer annual grass, biennial, and winter annual species (Buhler *et al*., 1995). Densities of large-seeded dicot species often decrease. The ecological and management aspects of these changes are varied and complex. Generally CA is believed to worsen weed problems, through higher weed emergence by concentration of seeds in surface soil layers, and shift of the weed community towards increased abundance of troublesome species, e.g. grasses and perennials (Spandl, *et al*., 1999; Barberi and Lo Cascio, 2001). Research by Ball and Miller (1993) showed that CA systems increased total weeds by about five times compared to a mould board system after five years. Other research has indicated a weed species shift, most commonly to more perennial weeds with reduced or no-till systems (Miller and Nalewaja, 1985; Mulugeta *et al*., 2001; Derksen *et al*., 1995). Under CA, weed seeds may still be protected from predation by insects, animals and birds because of self-burial as soils expand and crack with changes in moisture (Somody *et al*., 1985), thus allowing weeds to grow from seeds without tillage. Moreover, CA and no-till maintain a crop residue on the surface that keeps the soil cooler and moister, increasing survival of germinating small seeded weeds as compared to conventional tillage. All of these conditions will greatly influence the number and type of weed species.

As a result, labour demands for weeding under CA increase due to increased weed pressure while the source of labour is declining due to several factors including the spread of HIV/AIDS and the urbanisation in the farming communities in Zimbabwe. Labour constraints during peak periods of land preparation and weeding limit the area that small scale farmers can manage and often negatively impact on crop yields (Mmbaga, 1994). Although most farmers weed maize (*Zea mays* L) twice, some 21 % of farmers abandon up to 20 % of their cropped area each year as a result of poor crop establishment and weed competition (Ellis-Jones *et al*., 2001). According to Sibanda *et al*. (2001) less than 1 % of the resource poor farmers use herbicides because they do not afford to buy herbicides and equipment that is used to apply herbicides. Moreover lack of knowledge on how to use herbicides has also hindered uptake of chemical control in the smallholder sector. Effective, economical, and environmentally sound weed management in conservation agriculture systems will require integration of new information with established principles of weed management. New management systems and control technologies are needed to develop integrated weed management systems for the altered ecosystems created by CA production systems (Buhler *et al*., 1995). CA adoption rate and production improvements can be achieved by exploiting the use of GMCCs for weed management. GMCCs grow very fast and can cover the soil thereby preventing the germination of photoblastic weed seeds as well as growth of weeds by preventing the penetration of photosynthetic active radiation (PAR) to weeds growing below the canopy of GMCCs. Most of the GMCCs are planted as relay intercrops such that their shading effect on weeds alone would not help in the management of early season weeds that germinate together with the crop. It is therefore necessary to screen the common GMCCs for efficacy in suppressing the germination and emergence of the common arable weeds so that they can be used to achieve control of weeds during the critical weed free periods through functional allelopathy. Functional Allelopathy is the release of chemicals that are toxic (allelochemicals) to other plants as a result of transformation by microorganisms during decomposition of plant residues (Bezuidenhout, 2005). The use of allelopathic residues has been demonstrated to be an effective and environmentally friendly cultural weed control method. It has been reported that farmers in the United States of America have long recognized the difficulty of establishing crops in land previously infested

with quackgrass (*Agropyron repens* [L.] Beauv.) because this weed produces allelochemicals in its rhizomes and leaves that alter the growth of small grains and maize (Ross and Lembi, 1985). This phenomenon has been reported occasionally for weedy species but it has also been demonstrated in crop plants such as rice, rye and sorghum. Mashayamombe *et al*. (2013) reported that upright starbur (*Acanthospermum hispidum*), black jack (*Bidens pilosa*) and rapoko grass (*Eleusine indica*) are some of the dominant annual weeds of arable lands in Zimbabwe. There is therefore scope in identifying GMCCs that have allelopathic effects on common arable weeds in Zimbabwe. In this experiment, it was hypothesized that extracts of GMCCs have allelopathic effects on the germination, root and shoot length as well as emergence and dry matter accumulation of *Bidens pilosa, Eleusine indica* and *Acanthospermum hispidum*.

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Materials and Methods

Study site

The study was done in the laboratory and green house at the University of Zimbabwe's Crop Science Department in Harare, Zimbabwe (17.78^0S, 31.05^0E, 1523 meters above sea level). The University of Zimbabwe is in Natural Region II with an annual rainfall of 600-1000mm and average temperature of 20-30 ^{0}C.

Laboratory experiment

The laboratory experiment was laid out as a Randomised Complete Block Design (RCBD) with three blocks and different shelves were used as blocks. Eleven GMCCs and water were used as treatments and each treatment was replicated three times. The GMCCs that were used are Lab lab (*Dolicos bean*), Tephrosia (*Tephrosia vogelli*), Raphanus (*Raphanus sativa*), Black bean (*Phasiolus vulgaris*), Grahamiana (*Crotalaria grahamiana*), Jack bean (*Canarvalia ensiformis*), Sunhemp (*Crotalaria ochraleuca*), Sunhemp (*Crotalaria juncea*), Velvet bean (*Mucuna pruriens*), Common vetch (*Vicia sativa*), Cowpea (*Vigna unguiculata*) and distilled water was used as the control. Each of the GMCCs was planted in the greenhouse in large pots of 39 cm diameter and 40 cm height. The legumes were watered after every other day using a watering cane fitted with a fine rose. The plants were harvested just before flowering at about three weeks after planting (WAP). The roots and shoot of each legume were harvested and mixed in the same envelope before drying in the shed for three weeks. After drying the plant material was ground into fine powder using a hummer mill grinder. Twenty grams of each powder were dissolved in 300 ml of distilled water and left for 24 hours at room temperature. The extract was then filtered to remove the residues using a muslin cloth. The extracts were put in labeled 500 ml beakers and kept in a refrigerator for later use. A 9 cm diameter of Whatman filter paper was laid at the bottom of the petri dishes and 20 weed seeds were placed in each petri dish. The seeds of *B. pilosa*, *E. indica* and a local landrace of Pearl millet (*Pennisatum glaucum*) were treated separately in separate petri dishes with 5 millilitres of each GMCC extract and the petri dishes were properly closed using the lid to avoid moisture escape. The weed seeds were treated regularly with the same amount of each extract when the filter papers were about to dry. The petri dishes were placed in an incubator and the temperature was set at 30 ^{o}C until germination was noticed. Germination was defined as emergence of the radical or the hypocotyls to a length equal to the longest dimension of the seed. Data on germination percentage, root length and plumule length were measured using a 30 centimeter ruler after 14 days. Germination was expressed as a percentage. And percentage reduction was also calculated using the formula:

$$\%\ \text{reduction} = \frac{C - T}{C} * 100$$

Where C = number of seeds that emerged in the control and T = number of emerged seeds in the GMCC treatment.

Greenhouse experiment

The green house experiment was laid out as a Randomised Complete Block Design (RCBD). The same treatments that were used in the laboratory experiment were used in this experiment. The twelve treatments (eleven GMCCs + control) were arranged in three blocks with each treatment appearing once in each block. Blocking in the greenhouse was

according to the position of rows from the windows. The allelopathic potential of the legumes was evaluated using the method modified from Shiling *et al*. (1992) and Bewick *et al*., (1994). The ground powder of each of the GMCCs from the first experiment was used in this experiment. Pots of 20 cm diameter and 18 cm height were filled with red clay soil (texture) soil and 30 grams of each powder were thoroughly mixed with the soil in the top five centimeters of the pot and in the control no powder was applied. The assay species were *B. pilosa, E. indica* and *A. hispidum.* 100 seeds of *E. indica*, 30 seeds of *B. pilosa* and 30 *A. hispidum* were planted in each pot. The soil in the pots was watered to field capacity using a watering cane fitted with a fine rose.

Weed counts per species were taken from each pot starting at 6, 8, 13, 20, 23 and 28 days after planting (DAP). On the same day when the final weed count was taken, the weeds were harvested putting each weed species in its envelope. The harvested weeds were oven dried for 48 hours and weighed to obtain the dry matter. Germination percentage for each weed species was calculated by dividing the number of seeds that had germinated over the total seeds that were sown.

Data analysis

Data which were obtained in the laboratory and greenhouse were entered into excel and were subjected to analysis of variance (ANOVA) using Genstat version 14 at P < 0. 05. Mean separation was done using the protected least significance difference (LSD) at 5 % significance level.

Results

Laboratory experiments

Effect of GMCC extracts on the germination, radicle length and plumule length of Pearl millet *(Pennisatum glaucum*)

GMCC extracts had a significant effect (P< 0.05) on germination percentage of Pearl millet (Table 1). GMCC extracts significantly reduced the germination of Pearl millet except for Raphanus (*R. sativas*) and Grahamania (*C. grahamiana*) with both having the highest germination percentage. The percentage germination of Pearl millet (*P. glaucum*) ranged from 9 % to 91 % including the control. Cowpea was significantly (P < 0.05) more efficous in reducing the germination of pearl millet than all the other GMCCs. GMCC extracts had a significant (P < 0.05) effect on radical length of pearl millet. Most of the GMCC extracts significantly (P < 0.05) reduced the radical length except for Grahamiana which was not significantly (P < 0.05) different from the control and had the lowest percentage reduction. Extracts of all the GMCCs significantly (P < 0.05) reduced plumule length of Pearl millet. The percentage reduction for all the legumes ranged from 18 % to 98 %.

Table 1: Effect of GMCC extracts on the germination, radicle length and plumule length of Pearl millet (*Pennisatum glaucum*)

Plant Name	Scientific Name	% germination ± SE	Radicle		Plumule	
			Length (cm) ± SE	% Reduction	Length (cm) ± SE	% Reduction
Tephrosia	*Tephrosia vogelli*	50 ±5.40^{c}	0.36 ±0.21^{a}	96	1.4 ±0.21^{d}	86
Sunnhemp	*Crotalaria ochraleuca*	33 ±5.95^{b}	0.07 ±0.07^{a}	99	0.67 ±0.36^{abc}	93
Raphanus	*Raphanus sativas*	79 ±4.73^{d}	6.53 ±1.3^{a}	35	3.72 ±0.24^{e}	62
Black bean	*Phasoilus vulgaris*	29 ±4.27^{b}	0.01 ±0.01^{a}	99.99	0.79 ±0.19^{bcd}	92
Jack bean	*Canarvalia ensiformis*	36 ±5.15^{bc}	0.94 ± 0.12^{a}	90	1.10 ±0.11^{cd}	89
Sunnhemp	*Crotalaria*	26 ±4.47^{b}	0.16 ±0.06^{a}	98	0.66 ±0.32^{abc}	93

	juncea					
Common vetch	*Vicia sativa*	25 ±4.56[b]	0.04 ±0.02[a]	99.6	0.16 ±0.05[a]	98
Cowpea	*Vigna unguiculata*	9 ±5.15[a]	0.01 ±0.01[a]	99.99	0.21 ±0.18[ab]	98
Velvet bean	*Mucuna pruriens*	31 ±4.73[b]	0.02 ±0.03[a]	98	0.77 ±0.21[abc]	92
Grahamania	*Crotalaria grahamiana*	79 ±4.27[d]	8.62 ±0.21[b]	15	8.00 ±0.09[f]	18
Lab lab	*Dolicos bean*	38 ±6.07[bc]	0.01 ±0.01[a]	99.99	1.20 ±0.07[cd]	88
Distilled water	H_2O	91 ±2.39[d]	10.08 ±1.84[b]	0	9.68 ±0.26[g]	0
P value		P< 0.001	P< 0.001		P< 0.001	
LSD (0.05)		14.04	1.828		0.618	

Means bearing the same letters are not significantly different at P < 0.05.

Effect of GMCC extracts on the germination of *B. pilosa* and *E. indica*.

B. pilosa did not germinate in the incubator. However, *E. indica* had low germination in the control (distilled water) and Grahamiana with germination percentage of 25.0 ± 2.04 and 6.25 ± 1.25, respectively. *E. indica* only germinated where Grahamiana extracts were used. Germination percentage of *E. indica* seeds was significantly (P < 0.05) lower than the germination percentage of *E. indica* in the control.

Greenhouse experiments

Effect of GMCC biomass on the emergence of *B. pilosa*.

Table 2 shows that the GMCC biomass significantly (P < 0.05) reduced *B. pilosa* emergence. The percentage reduction of *B. pilosa* ranged from 54 % to 83 %.

Table 2: Effect of GMCC biomass on the final emergence of *B. pilosa*

Plant Name	Scientific name	Number of emerged weeds ± SE	% Reduction
Tephrosia	*Tephrosia vogelli*	7 ± 0.6[ab]	70
Sunnhemp	*Clotalaria ochraleuca*	4 ±0.6[a]	83
Raphanus	*Raphanus sativas*	5 ±0.7[ab]	77
Black bean	*Phasiolus vulgaris*	10 ±0.9[b]	55
Jack bean	*Canarvalia ensiformis*	4 ±0.3[a]	81
Sunnhemp	*Crotalaria juncea*	6 ±1.3[ab]	75
Common vetch	*Vicia sativa*	7 ±1.2[ab]	70
Cowpea	*Vigna unguiculata*	8 ±2.7[ab]	65
Velvet bean	*Mucuna pruriens*	8 ±1.7[ab]	65
Grahamania	*Crotalaria grahamiana*	6 ±1.7[ab]	73
Lab lab	*Dolicos bean*	11 ±4.2[b]	54
Control (Soil)		23 ±3.1[c]	0
P value		P < 0.001	
LSD (0.05)		13.75	

Means bearing the same letters are not significantly different at P< 0.05.

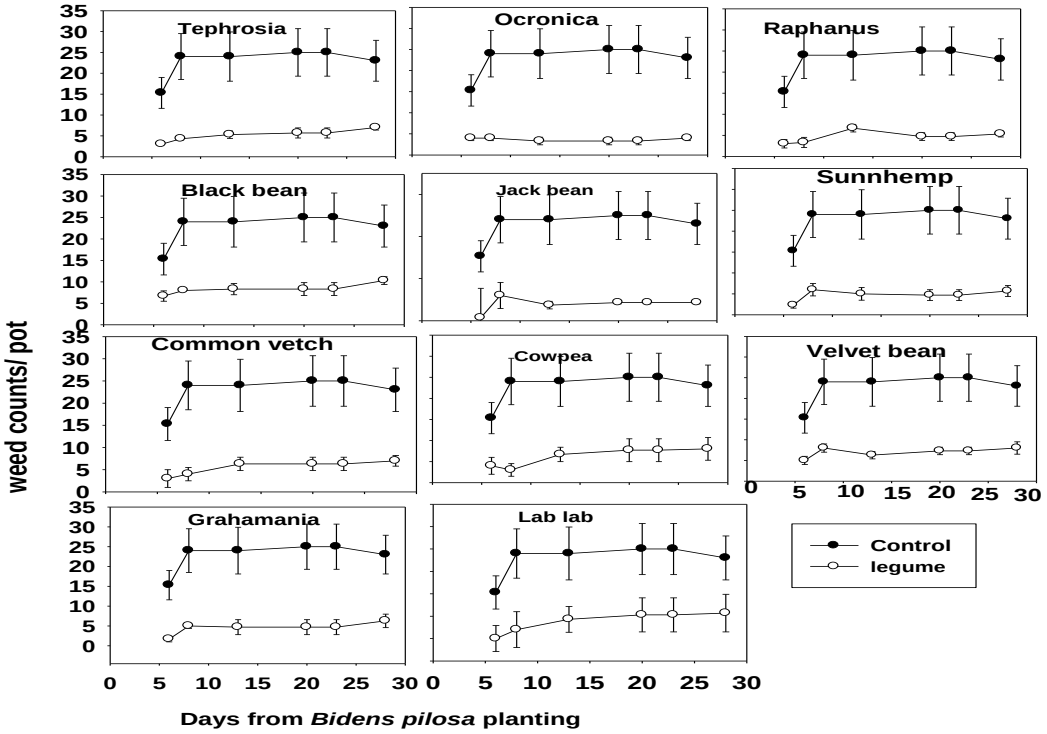

Fig 1 . Effect of leguminous cover crops on the emergence of *Bidens pilosa* from first day of counting upto last day of counting.

Figure 1 shows that *B. pilosa* counts were significantly reduced by all the GMCCs that were used in this experiment from 6 DAP to 28 DAP.

Effect of GMCC biomass on the emergence of *E. indica.*

All GMCCs significantly reduced ($P < 0.05$) the emergence of *E. indica* (Table 3). The reduction of *E. indica* ranged from 28 % to 67 % as compared to the control. The greatest reduction was seen where Raphanus and Jack bean were used.

Table 3: Effect of GMCCs on the final emergence of *E. indica*

Plant Name	Scientific Name	Number of emerged weeds ± SE	% Reduction
Tephrosia	*Tephrosia vogelli*	59 ±8.2^{d}	28
Sunnhemp	*Crotalaria ochroleuca*	42 ±2.9^{bc}	48
Raphanus	*Raphanus sativas*	31 ±3.0^{ab}	62
Black bean	*Phasiolus vulgaris*	42 ±3.3^{bc}	48
Jack bean	*Canarvalia ensiformis*	27 ±3.5^{a}	67
Sunnhemp	*Crotalaria juncea*	53 ±5.2^{cd}	35
Common vetch	*Vicia sativa*	48 ±1.2^{cd}	41
Cowpea	*Vigna unguiculata*	49 ±7.4^{cd}	40
Velvet bean	*Mucuna pruriens*	51 ±2.5^{cd}	37
Grahamania	*Crotalaria grahamiana*	49 ±5.9^{cd}	40
Lab lab	*Dolicos bean*	46 ±3.2^{cd}	43
Control (soil)		81 ±7.3^{e}	0
P value		P < 0.001	
LSD (0.05)		13.75	

Means showing the same letters are not significantly different at P< 0.05.

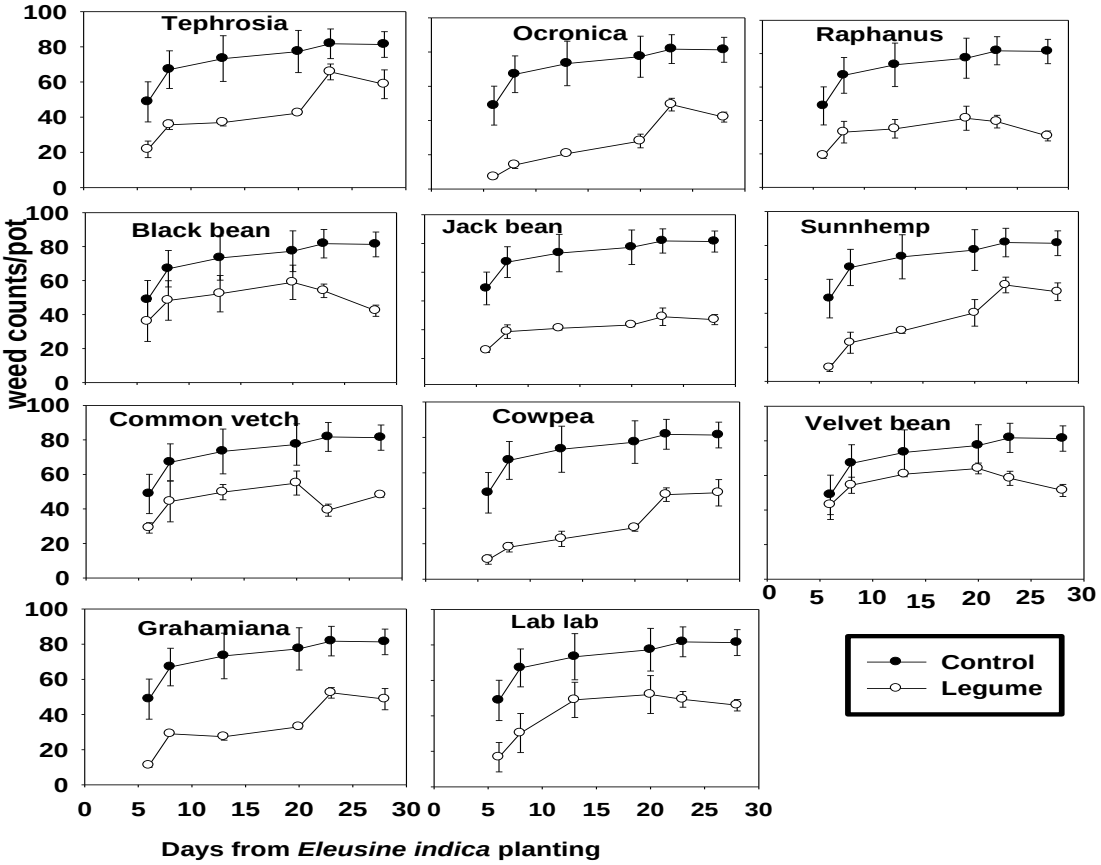

Fig 2 shows the effect of leguminous cover crops on the emergence of *Eleusine indica* from day of planting up to last count.

The density of *E. indica* was significantly (P < 0.05) reduced from 6 DAP up to 28 DAP where the biomass of Tephrosia, Ocronica, Raphanus, Jack bean, Sunnhemp, Cowpea, Grahamiana and Lab lab were used (Figure 2). Biomass of common vetch, black bean and velvet bean only started to cause a significant reduction on *E. indica* emergence after the fourth weed count.

Effect of GMCC biomass on the emergence of *A. hispidum*.

The effect of GMCCs on the emergence of *A. hispidum* was significant (P < 0.001). All the GMCCs did not significantly reduce the emergence of *A. hispidum* except for common vetch which stimulated the emergence of *A. hispidum* (Table 4).

Table 4: Effect of GMCC biomass on the emergence *A. hispidum*

Plant Name	Scientific name	Number of emerged weeds ± SE	% Reduction
Tephrosia	*Tephrosia vogelli*	4 ±1.2[a]	14
Sunnhemp	*Crotalaria ochraleuca*	4 ±1.2[a]	14
Raphanus	*Raphanus sativas*	5 ±0.7[a]	6
Black bean	*Phasiolus vulgaris*	5 ±1.2[a]	0
Jack bean	*Canarvalia ensiformis*	7 ±0.3[a]	0
Sunnhemp	*Crotalaria juncea*	4 ±0.7[a]	14

Common vetch	*Vicia sativa*	14 ±1.2[b]	0
Cowpea	*Vigna unguiculata*	5 ±0.9[a]	0
Velvet bean	*Mucuna pruriens*	5 ±0.9[a]	0
Grahamania	*Crotalaria grahamiana*	5 ±1.5[a]	0
Lab lab	*Dolicos bean*	7 ±2.3[a]	0
Control (soil)		5 ±0.0[a]	0
P value		P < 0.001	
LSD (0.05)		3.5	

Means bearing the same letters are not significantly different at P < 0.05.

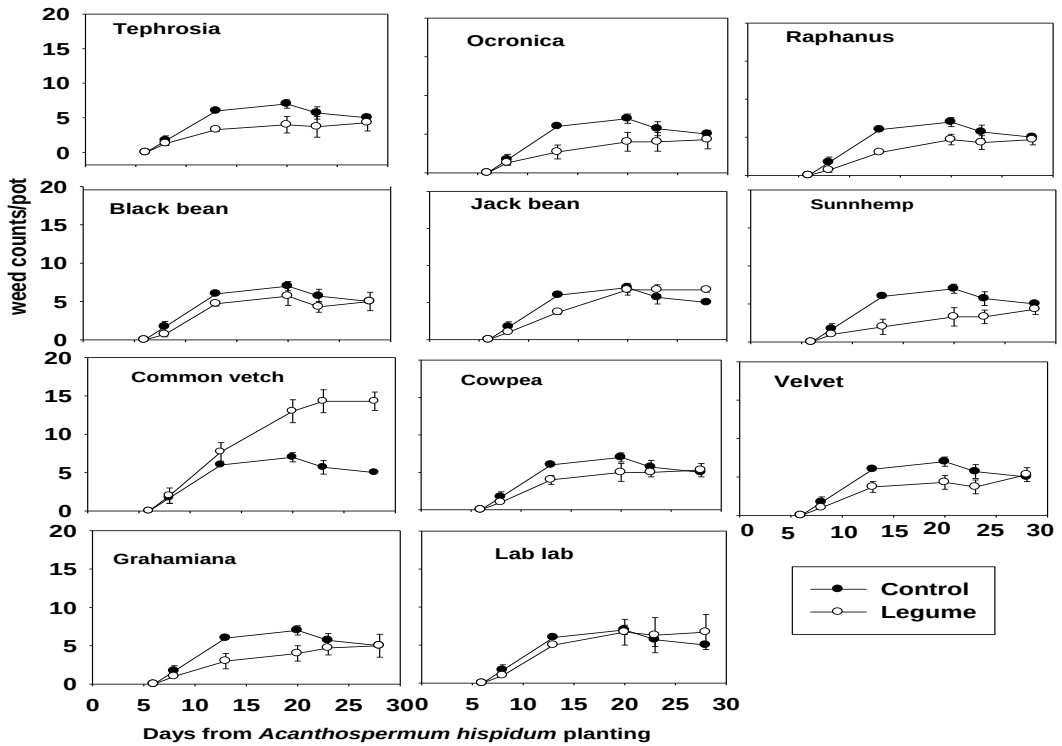

Fig 3. Effect of leguminous cover crops on the emergence of *Acanthospermum hispidum* from first day of counting upto last day counting.

Figure 3 shows that residues of common vetch had a stimulatory effect on the emergence of *A. hispidum* from 13 DAP to 28 DAP. All the other GMCC had no significant effect on the germination of *A. hispidum* throughout the duration of the experiment.

Effects of GMCC biomass on the dry matter of *B. pilosa, E. indica* and *A. hispidum.*

Biomass of all the GMCCs significantly (P < 0.05) reduced *B. pilosa* and *E. indica* dry matter (Table 5). Dry matter of *A. hispidum* was significantly (P < 0.046) reduced by all the other GMCCs except common vetch and cowpea.

Table 5: Effect of GMCC biomass on the dry matter of *B. pilosa*, *E. indica* and *A. hispidum*

Plant Name	Scientific Name	*B. pilosa*		*E. indica*		*A. hispidum*	
		Dry matter (g) ± SE	% Reduction	Dry matter (g) ± SE	% Reduction	Dry matter (g) ± SE	% Reduction
Tephrosia	*Tephrosia vogelli*	0.59 ±0.1^{ab}	75	4.44 ±0.7^{cd}	36	0.14 ±0.1^{abc}	67
Sunnhemp	*Crotalaria ochraleuca*	0.72 ±0.2^{ab}	70	2.54 ±0.3^{ab}	64	0.18 ±0.1^{abc}	57
Raphanus	*Raphanus sativas*	0.12 ±0.0^{a}	95	1.65 ±0.4^{a}	76	0.10 ±0.0^{a}	76
Black bean	*Phasoilus vulgaris*	0.52 ±0.3^{ab}	78	2.22 ±0.5^{ab}	68	0.17 ±0.1^{abc}	60
Jack bean	*Canarvalia ensiformis*	0.19 ±0.0^{a}	92	2.41 ±0.1^{ab}	65	0.23 ±0.0^{abc}	45
Sunnhemp	*Crotalaria juncea*	0.47 ±0.1^{ab}	80	3.27 ±0.5^{bc}	53	0.11 ±0.1^{ab}	74
Common vetch	*Vicia sativa*	0.13 ±0.3^{a}	95	2.54 ±0.3^{ab}	64	0.32 ±0.0^{cd}	24
Cowpea	*Vigna unguiculata*	1.12 ±0.5^{ab}	53	3.93 ±0.7^{c}	44	0.29 ±0.1^{bcd}	31
Velvet bean	*Mucuna pruriens*	0.83 ±0.6^{ab}	65	5.28 ±0.7^{d}	24	0.12 ±0.0^{ab}	71
Grahamania	*Crotalaria grahamiana*	0.59 ±0.2^{ab}	75	3.98 ±0.6^{cd}	43	0.19 ±0.0^{abc}	55
Lab lab	*Dolicos bean*	1.31 ±0.6^{b}	45	3.34 ±0.5^{bc}	52	0.23 ±0.1^{abc}	45
Control (soil)		2.36 ±0.8^{e}	0	6.97 ±0.2^{e}	0	0.42 ±0.1^{d}	0
P value		P < 0.009		P < 0.001		P < 0.046	
LSD (0.05)		1.025		1.350		0.189	

Means bearing the same letters are no significantly different at P< 0.05.

Discussion

Extracts of all the GMCCs had a negative impact on the germination of Pearl millet (*P. glaucum*), except for Raphanus (*R. sativas*) and Grahamiana (*C. grahamania*) which were seen to have no impact on the germination of Pearl millet. This suggests that the residues of most of these GMCCs have allelochemicals that have a detrimental effect on pearl millet germination. These results concur with finding by Machado (2007) who reported that Meadow foam (*Limnanthes alba)* was able to reduce the growth of Downy brome (*Bromus tectorum*), a weed in wheat (*Triticum aestivum*) but at the same time it was toxic to wheat itself. This implies that intercropping or growing Pearl millet where residues of these GMCCs have been incorporated in the soil might have a negative effect on the emergence of Pearl millet. These findings clearly demonstrate that allelochemicals are not suppressive to weeds only but can also be harmful to other crops.

All the legumes were able to reduce the radicle and plumule length of Pearl millet except for Grahamania and Raphanus which showed the least potential in reducing the plumule length of Pearl millet. This may indicate that, extracts that allowed rapid germination also allowed more time for radicle and plumule growth compared to extracts that delayed germination. Reduction in the plumule and radicle length may be a reflection of delayed germination rather than direct effect of the allelochemicals.

Seeds that were used in both the laboratory and the green house experiments were taken from the same lot. However, *B. pilosa* seeds did not germinate in the incubator at 30 ^{o}C but germinated in the greenhouse. This shows that failure of *B. pilosa* seeds to germinate in the incubator was a result of dormancy and not loss of viability. Information on the photoperiodic requirements of *B. pilosa* is not available. However the failure of seed to germinate under continuous darkness in the incubator suggests that the seeds of this weed may require exposure to alternating light and darkness other than continuous darkness for it to germinate as suggested by Egley (1999) who reported that

some seeds require an alternation of darkness and light so that they can germinate.

The results clearly show that most of the legumes which were screened in this study have an effect on the emergence and dry matter production of *B. pilosa*, *E. indica* and *A. hispidum*. These findings concur with findings by Hill *et al*. (2006) who reported that *Crotalaria juncea* had some inhibitory effect on *A. hypochondriacus* and *A. retroflexus. Similar results were also obtained* by Adler and Chase, (2007) who reported that biomass of Sunnhemp (*C. juncea*), Cowpea (*V. unguiculata*) and Velvet bean (*M. pruriens*) had an inhibitory effect on *Amaranthus* species. Allelochemicals such as L-3-(3, 4 dihydroxyphenylalamine) produced by the leaves of *Mucuna pruriens* (Fujii, 1999), a non protein amino acid delta-hydroxynorleucine (5- hydroxyl 1-2-aminohexanoic acid) produced by *Crotalaria* species (Pilbeam and Bell, 1979) and quinolizidine alkaloids produced by legumes of *Phasiolus vulgaris* could be some of the compounds that are responsible for suppression of germination in these weed species.

Although some GMCCs used in this study have not shown outstanding potential of inhibiting the emergence of *B. pilosa*, they delayed the emergence of this weed. GMCCs such as Lab lab (*Dolicos bean*) and Black bean (*Phasiolus vulgaris*) resulted in a delay in the emergence of *B. pilosa* over time. This delay might have an effect on the critical weed control period. A delay in weed emergence may give enough time to the crop to grow before it is harmed by the weeds (Hartzler, 2003). When the weeds emerge late this will give the crop a competitive advantage and it might not be economic to control these late weeds afterwards using other weed control methods (Knezevic *et al*., 2002).

Biomass of *B. pilosa*, Raphanus (*R. sativas*), Jack bean (*C. ensiformis*), Common vetch (*V. sativas*) and Sunnhemp (*C. juncea*) showed an outstanding reduction in the dry matter of Black jack (*B. pilosa*). The ability of these legumes to reduce the dry matter might indicate that these legumes might have post emergence herbicidal properties (Adler and Chase, 2007). Common vetch (*Vicia sativas*) did not reduce the emergence of *B. pilosa*, but had an impact on the dry matter, which suggests that the type of allelochemicals that are found in this GMCC have an inhibitory effect on other physiological processes other than germination and emergence.

The GMCCs had an inhibitory effect on the emergence of *E. indica.* Similar results were obtained by Adler and Chase (2007) who reported that Raphanus (*R. sativas*) and Jack been (*C. ensiformis*) have the highest potential in suppressing the emergence of *E. indica*. The fact that these two GMCCs also have an effect on *B. pilosa* suggests that they have broad spectrum activity. The trend of emergence of *E. indica* from day of planting up to the day of harvesting shows that these GMCCs apart from inhibiting emergence and dry matter are also capable of delaying the emergence of weeds. Generally results from this study have demonstrated that the GMCCs that are commonly used in rotations under CA systems also have a suppressive effect on weeds, both as a result of allelochemicals that they produce and also as a result of the smothering effect that they have on weeds because they produce a lot of biomass.

Conclusion and Recommendations

Most plant species screened in this study, in particular Jack bean (*Canarvalia ensiformis*), Sunnhemp (*Crotalaria juncea*), Sunnhemp (*Crotalaria ochraleuca*), Grahamania (*Crotalaria grahamania*), Velvet bean (*Mucuna pruriens*) and Raphanus (*Raphanus sativas*) have shown the highest inhibitory effect on the three weeds under this study. These legumes have a great potential of controlling *B. pilosa, E. indica* and *A. hispidum* in cropping systems. Additional work is needed to test the efficacy of residues and extracts from these plants on weed control under field conditions and to test them on different weed species. There is also a need to isolate and identify the actual allelochemicals that are produced by these GMCCS.

References

Adler, J. M. and Chase, A. C. (2007). A Comparison Analysis of the Allelopathic

Potential of Leguminous Summer Cover crops: Cowpea, Sunhemp, Velvet bean. Hortscience, 42: 289-293.

Ashburner, J. E. (1984). Dryland tillage practices and studies in Algeria. F.A.O Panel of experts on Agricultural mechanisation, 6th Session, Adana, Turkey, October 1984: 22.

Ball, D. A. and Miller, S. D. (1993). Cropping history, tillage effects on weed flora composition in Irrigated corn. Agronomy Journal, 85: 817-821.

Barberi, P. and Lo Cascio, B. (2001). Long-term tillage and crop rotation effects on weed seed bank size and composition. Weed research, 41: 325-340.

Bewick, T. A., Shilling, D. G., Dusky, J. A. and William, D. (1994). Effects of Celery (*Apium graveoleus*) root residue on growth of various crops and weeds. Weed technology, 8: 625-629.

Bezuidenhout, R. S. (2005). Allelopathy as a possible cause of yield reduction, Weed science journal, 2: 16-18.

Buhler, D. D., Doll, J. D., Proost, R. T. and Visocky M. R. (1995). Integrating mechanical Weeding with Reduced herbicide use in conservation tillage corn production systems. Agronomy Journal, 87: 507-512.

Derksen, D. A., Thomas, A. G., Lafond, G. P., Loeppky, H. A. and Swanton, C. J. (1995). Impact of Post emergence herbicides on weed community diversity within conservation-tillage systems. Weed Research, 35: 311-320.

Derpsch, R. (2008). No Tillage and Conservation Agriculture: A progress report, In: Goddard, T., Zoebisch, M., Gan, Y., Ellis, E., Watson, A. and Sombatpanit, S. *No till Farming Systems*. Special Publication No. 3. The World Association of Soil and Water Conservation (WASWC). Bangkok. Thailand.

Egley, G. H. (1999). Reflection on my career in seed germination research. Seed Science research, 9: 3-12

Ellis-Jones, J., Mavhudzi, Z., Muzenda, J., Chivinge, O., Riches, C., Chikwanda, M. and Nehanda, G.J. (2001). Mid season farmer evaluation of cotton weed management trials, Lower Muzarabani. Project Document IDG/01/10, Silsoe Research Institute. Bedfordshire, UK.

FAO (2007). Conservation Agriculture Website. http: //www.fao.org/ag/ca/ (verified 16/04/07).

Fujii, Y. (1999). Allelopathy of Hairy vetch and Mucuna: Determination of L-DOPA as a candidate of allelopathic substance. In: H.G Cutler and S.J Cutler (Eds), Biologically Active Natural products, CRC Press, Boca, Raton, FL, USA, pp 33- 48.

Harrington, L. and Erenstein, O. (2005). Conservation agriculture and resource conserving Technologies - A global perspective. Agromeridian, 10: 32-43.

Hartzler, B. (2003). Critical periods of competition. Agronomy journal, 2: 4-7.

Hill, E. C., Ngouajio, M. and Nair, M. G. (2006). Differential response of weeds and vegetable Crops to aqueous extracts of Hairy vetch and Cowpea. Hort Science, 41: 695-700.

Hobbs, P. R. (2007). Conservation agriculture: what is it and why is it important for future sustainable food production? Journal of Agricultural Science, 145(2): 127-137.

Knezevic, S. Z., Evans, S. P., Blankenship, E. E., Van Acker, C. R. and Lindquist, J. L. (2002). Critical period for weed control. Weed science, 9: 773-786.

Machado, S. (2007). Allelopathic potential of various plant species on Downy Brome: Implication for weed control in wheat production. Agronomy journal, 99: 127-131.

Mashayamombe, B. K., Mazarura, U. and Chiteka, A. (2013). Effect of two Formulations of Sufentrazone on Weed Control in Tobacco (*Nicotiana Tabacum* L). Asian journal of Agriculture and Rural Development, 3(1): 1-6.

Miller, S. D. and Nalewaja, J. D. (1985). Weed spectrum change and control in reduced-till wheat. North Dakota Farm Research, 43(1): 11-14.

Mmbaga, T. E. (1994). Chemical weed control in maize-bean intercropping. In: Jewell, D.C., Ramsom, J.K., Pixley, K.V. (Eds). Proceedings of the fourth Eastern and Southern Africa regional maize conference, Harare, Zimbabwe.

Mulugeta, D., Stoltenberg, D. E. and Boerboom, C. M. (2001). Weed species-area relationships as influenced by tillage. Weed Science, 49: 217-223.

Pilbeam D. J. and Bell, A. E. (1979). A Reappraisal of the Free Amino acids In Seed of *Crotalaria juncea* (Leguminosae). Phytochemistry, 18: 320-321.

Ross, M. A. and Lembi, C. A. (1985). Applied Weed Science. Burgess Publishing Company. Minneapolis. Minnesota. USA.

Sayre, K., Govaerts, B., Martinez, A., Mezzalama, M. and Martinez, M. (2006). Comparison of Alternative conservation agriculture technologies for rain fed production in the highlands of Central Mexico. Proceedings on CD, 17th ISTRO Conference, Kiel, Germany, 28 Agust-3 September 2006:1012 - 1018.

Shilling, D. G., Dusky, J. A., Mosser, M. A. and Bewick, T. A. (1992). Use of the cover crops Weed Index to evaluate weed suppression by cover crops in Organic Citrus Orchards. Horticultural Science Journal, 43: 27-33.

Sibanda, S., Barton, A., Ellis-Jones, J., Nyakudya, E., Mashingaidze, A. B., Chivinge, O. A. and Riches, C. (2001). Weed management in cotton productions systems: A case study from The Zambezi Valley, Zimbabwe. In: Garcia-Torres, L., Benites, J. and Martinez-Vilela, A. Conservation agriculture, a World challenge. XUL, Cordoba, Spain.

Somody, C. N., Nalewaja, J. D. and Miller, S. D. (1985). Self-burial of wild oat florets. Agronomy Journal, 77: 359-362.

Spandl, E., Durgan, B. R. and Forcella, F. (1999). Foxtail (*Setaria* spp) seedling dynamics in Spring Wheat (*Triticum aestivum*) are influenced by seeding date and tillage regime. Weed Science, 47: 156-160.

Wall, P. (1999). Experiences with crop residue cover and direct seeding in the Bolivian highlands. Mountain Research and Development, 19(4): 313-317.