Greener Journal of Agricultural Sciences
ISSN: 2276-7770; ICV: 6.15
Vol. 5 (2), pp. 062-075, March 2015

http://gjournals.org/GJAS

Research Article *(DOI: http://doi.org/10.15580/GJAS.2015.2.082914341)*

The effect of Herbicides on Residual Effects of Atrazine under Conservation Agriculture

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ARTICLE INFO

Article No.: *082914341*
DOI: *10.15580/GJAS.2015.2.082914341*

Submitted: *29/08/2014*
Accepted: *22/03/2015*
Published: *27/03/2015*

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Keywords:
conservation agriculture, atrazine, cowpea, residual effect

ABSTRACT

An experiment was set up to evaluate the residual effect of atrazine in cowpea production under conservation agriculture. The trial was superimposed on a previous herbicide trial of a maize crop in 2012/2013 season. The experiment was laid out in a randomized complete block design with three replicates and four treatments as follows; 1. control (manual weeding), 2. Atrazine (3.6 litres/ha), 3. Atrazine (3.6 litres/ha) + glyphosate (2.5 litres/ha) and 4. Atrazine (3.6 litres/ha) + glyphosate (2.5 litres/ha) + metolachlor (1 litre/ha). Herbicide treatment was carried out at planting time and manual weeding at 10 cm weed height. Data collected include: germination percentage, weed counts and weed biomass, cowpea biomass, pod length and cowpea yield. The herbicidal treatments showed a significant effect ($p<0.05$) on pod length and cowpea yield. The control plot had the highest pod length of 17.03cm and atrazine alone had the least of 15.77cm. A combination of three herbicides had the highest yield of 1.2t/ha and atrazine alone had the lowest yield of 0.9t/ha. No significant ($p>0.05$) effects were recorded on percentage germination, weed counts and weed biomass as well as on cowpea biomass. Tank mixing of two or more herbicides is recommended when using atrazine to reduce residual effect and further research is recommended under different soil types with different climatic conditions.

INTRODUCTION

In Zimbabwe smallholder farmers occupy 1.6 million hectares of the country and their average maize (*Zea mays* L) yield is 0.8 t/ha (Baudron *et al.*, 2012). The low maize yields are a result of increased rate of natural resources degradation (Munodawafa, 2012). Farmers have relied on the use of mouldboard ploughs and hand hoes for land preparation since 1920 (Johansen *et al.*, 2012). The side effects of tillage-based agriculture practices without sufficient organic matter inputs has led to land degradation and soil erosion that can be as high as 12 tonnes per hectare in many parts of the country leading to decline in productivity and food insecurity (Wall 2007; Thierfelder and Wall, 2009). Crop production in Zimbabwe is also adversely affected by uneven rainfall distribution due to climate variability (Niggol *et al.*, 2009). Promotion of more sustainable agricultural systems with potential to reduce the effects of soil degradation and climate change will improve the livelihoods of smallholder farmers. Conservation agriculture is one of the systems currently proposed to reduce the impacts of climate change and land degradation (Lal *et al.*, 2011).

Food and Agricultural Organization of the United Nations (2002), describes conservation agriculture as 'a way of farming that conserves, improves and makes more efficient use of natural resources through integrated management of the available resources combined with external input. It is based on three basic principles of minimum soil disturbance, maintenance of a permanent soil cover through residue retention and/or the use of green manure cover crops and crop rotations. Reduced tillage under conservation agriculture prevents soil inversion that exposes buried weed seeds to the soil surface where conditions are favourable for germination. More weed seeds will accumulate on or near the surface (Ghosheh and Al-Hajaj, 2005), where there are likely to germinate in one season and highly exposed to predation. The weed seed bank can be depleted through weeding of all emerged weeds before they set seed. However, due to minimum soil disturbance in conservation agriculture, there is a change in weed flora from broadleaved weeds to perennial grasses (Derpsch, 2008). Retention of residues under conservation agriculture hinders manual weeding that can lead to difficulties in depleting the weed seed bank. Use of herbicides to improve weed management practices under conservation agriculture has been promoted. In Zimbabwe, the commonly used herbicides are; atrazine, glyphosate, paraquat and dual. Atrazine, which is commonly used in maize systems, is a pre-emergent photosynthetic inhibitor of broadleaf weeds that has been reported to injure vegetative crops from previous herbicide application (Peyvastegan and Farahbakhsh, 2011). It has long herbicide residual effects and its persistence is dependent on soil type (Croplife, 2006) hence; it may affect crop rotations especially if broadleaved crops are included.

Soil composition affects herbicide phytotoxicity and persistence through adsorption, leaching, and volatilization (Croplife, 2006). Generally, soils high in clay, organic matter, or both have a greater potential for herbicide carryover because there is increased adsorption to soil colloids, with a corresponding decrease in leaching and volatilization losses (Aaron *et al.* 2007). Therefore, more herbicide is held in reserved form to be released later, potentially injuring susceptible future crops. Reduced doses of atrazine and improved microbial activity can promote faster atrazine degradation (Krutz *et al.*, 2009) which may reduce atrazine carry over problems in rotations with broadleaved crops under conservation agriculture. Thus, change of micro environment under conservation agriculture may contribute to faster degradation of atrazine making it ideal under conservation agriculture practices. Research has shown that chemical weed control options are more effective than manual weeding under conservation agriculture (Vogel, 1994; Rugare, 2009 Muchineripi, 2010). Thus, this research seeks to analyse the residual effect of atrazine on cowpea under conservation agriculture.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at the Institute of Agricultural Engineering (IAE) which is located 21km north-west of the city of Harare, along Harare Domboshava road. The site has a grid reference of 17^{o} 42'S and 31^{o}06'E and an altitude of 1 500 m above sea level (Machekano *et al.,* 2012). IAE is characterised by deep well drained soils classified as *Chromic Luvisols* and these soils have more than 60 % clay content and falls under agroecological region (II) of Zimbabwe (Nyamapfeni,1991). The annual rainfall experienced during the period of the experiment in the area ranged between 750 and 1000mm per annum with most of the rain falling between the month of November and March. The mean annual temperature ranged between 15 to 30 ^{0}C, during the same period (Muzemu *et al.,* 2011).

Experimental design and treatments

The experiment was laid out as a randomised complete block design (RCBD) with four treatments replicated three times. Each plot had a gross size of 37.8 m^2 and a net plot of 24m^2 with a spacing of 0.45 m between the rows and 0.15 m within the row. This experiment was superimposed on the plots where maize was grown using herbicides under the 2012-2013 season with the treatments shown in table1 below.

Table 1: Treatments that were used under maize weed control strategy

Treatment	Weed control strategy
Control	Manual weeding at 10 cm weed height.
Atrazine	Application of 3.6 litres /ha of atrazine at planting time + manual weeding at 10 cm weed height.
Atrazine + Glyphosate	Application of 2,5 litres/ha of glyphosate + 3.6 litres/ha of atrazine at planting time + manual weeding at 10 cm weed height.
Atrazine + Glyphosate + Dual	Application of 2,5 litres/ha of glyphosate + 3.6 litres/ha of atrazine + 1litre/ha of metolachlor at planting time + manual weeding at 10 cm weed height.

Trial management

Maize residues were uniformly spread in each plot at a rate of 2.5 tonnes per ha after marking the plots. Cowpea crop cultivar CBC2 was used in the experiment. A ripper was used to open up the furrows for planting. Planting was carried out with the first effective rains. A basal fertilizer of compound D (N7: P14: K7) was applied at 200 kg per ha and no nitrogen top dressing was applied because cowpea has the potential to fix nitrogen (Bohlool, et al, 1992). The plots were kept weed free by hand hoeing. Aphid incidences were controlled with carbaryl 85% WP. Hand harvesting of the crop was carried out at 12 weeks after planting.

Data collection

Germination percentage was recorded at 50% emergence. Above ground biomass was collected in each plot every fortnight by destructive sampling. Ten cowpea plants were randomly cut at ground level from each plot weighed for fresh weights. These were then oven dried at 80^0C for 48 hours to obtain dry weight. Weed counts and weed biomass were taken prior to each weeding operation. Quadrat sampling (0.5m x 0.5m) was used to determine species composition. Four quadrants were randomly selected from each plot. A sample of five pods was randomly selected from each plot for recording pod length. The cowpeas were harvested from the net plot and allowed to dry under the open sun. Shelling of the cowpea was done and the grain weight was recorded.

Data Analysis

Analysis of variance was carried out using Genstat version 12 and mean separation was done using the least significant differences at 0.05 probability level.

Statistical Analysis

Analysis of variance was carried out using Genstat version 12 and mean separation was done using the least significant differences at 0.05 probability level to determine treatments on cow pea percentage germination, pod length, weed counts and weed biomass, cow pea biomass and cow pea yield.

RESULTS AND DISCUSSION

Percentage Germination

There was no significant difference among the treatments ($p>0.05$) in percentage germination of cowpea. At germination, atrazine residue had not yet affected the cowpea. These results concur with the results obtained by Taber (2009) on his work on sweet corn-snap beans rotations where emergence and early growth of snap beans were not affected by residual herbicide.

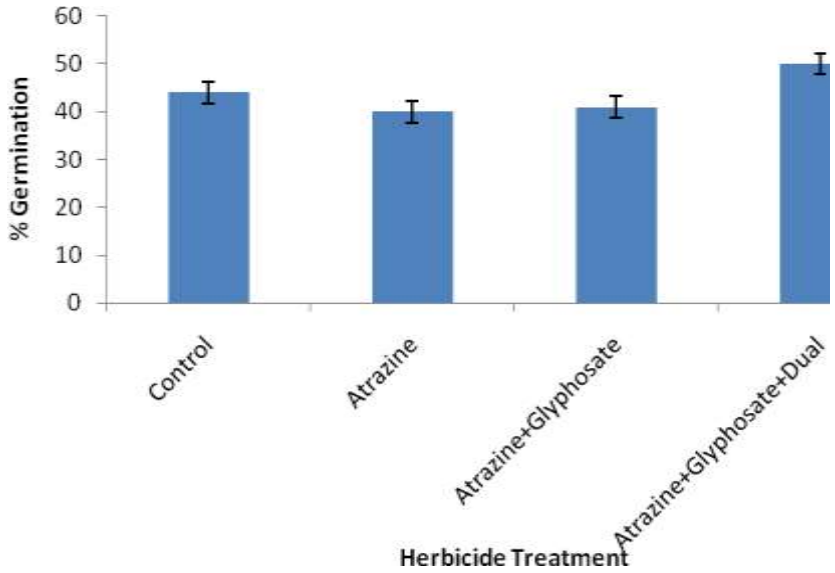

Figure 1: Effect of residual herbicide on germination of cowpea
Vertical bars represent standard error bars of means

Effect of herbicide on pod length

A significant difference ($p<0.05$) was observed among treatments with respect to pod length. The control treatment had the highest pod length of 17,03cm because there was no herbicide applied to it and therefore the cowpea was not affected. Atrazine alone had the least pod length of 15.77cm (Figure 2). This is because when atrazine is applied alone it tends to have more residual effect on the crop (Reinhardt, 1995). Moreover, no significant effect ($p>0.05$) between control and a combination of three herbicides was observed. The three treatments with herbicides showed no significant differences among themselves (Figure 2). This is because having been established in clay soils (Nyamapfene, 1991) under conservation agriculture there is high herbicide adsorption (Süzer and Büyük, 2010). There was no significant effect between the control treatment and a combination of three herbicides ($p>0.05$). This is because tank mixing two or more herbicides reduces the residual effect of atrazine (Aaron *et. al* .2007; Djumalieba and Vassilev, 1993).

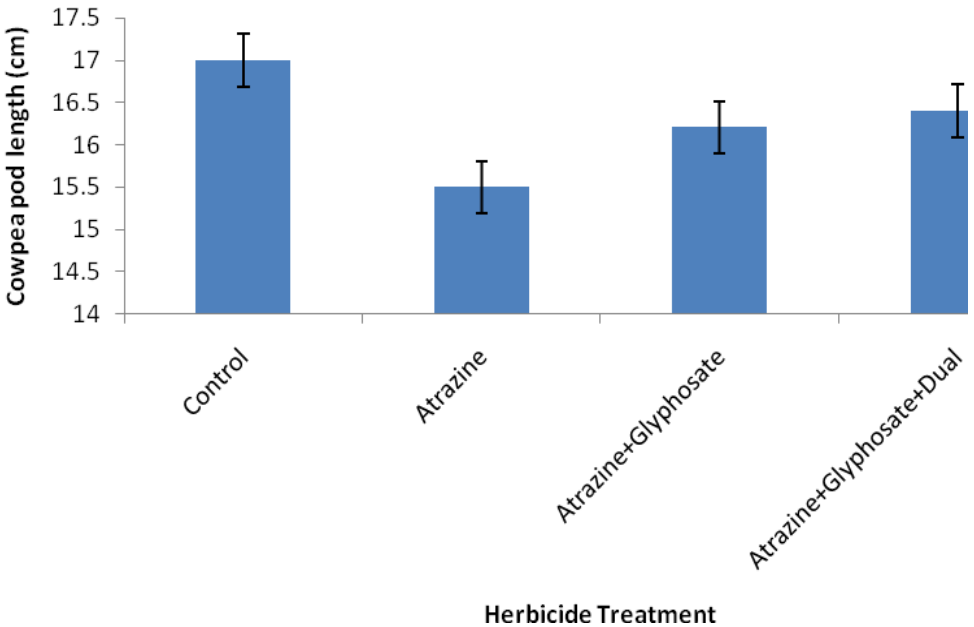

Figure 2: The effect of herbicide on pod length of cowpea
Vertical bars represent standard error bars of means

Weed counts and weed biomass

There was also no significant difference among treatments ($p>0.05$) with respect to weed counts and weed biomass. These results concur with results obtained by Verma et al, (2009) on their work on maize-green-gram cropping systems.

Cowpea biomass

The residual herbicide showed no significant effect on cowpea biomass ($p>0.05$) in each week. The above normal rains received during the 2013/2014 season reduced the effect of herbicide carryover (Esterhuizen, 2014). Constantly moist soil and excessive rainfall might have promoted herbicide breakdown or leaching below the crop root zone.

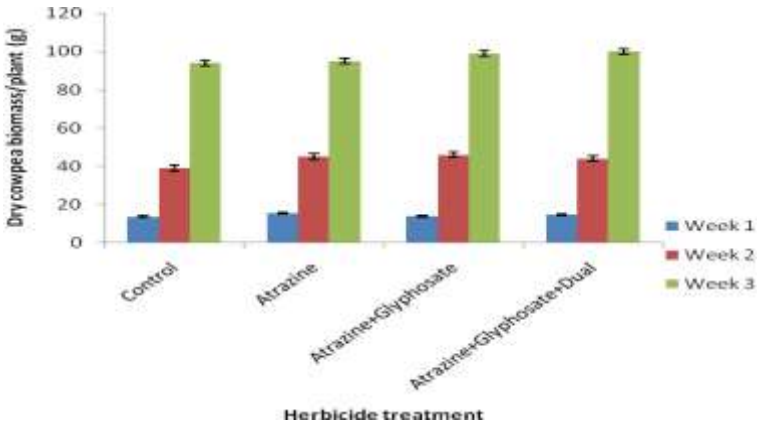

Figure 3: Effect of residual herbicide on fresh and dry cowpea biomass
Vertical bars represent standard error bars of means

Effect herbicide on cowpea yield

A significant effect of herbicide on cowpea yield was observed ($p<0.05$). Atrazine had the lowest yield of 0.9t/ha (Figure 4). When atrazine is applied alone it tends to have a residual effect on the successive crop (Reinhardt, 1995). A combination of three herbicides had the highest yield of 1.2t/ha but no significant differences were observed between a combination of three herbicides and control plot. This could be because tank mixing two or more herbicides reduces the residual effect. Hager and Nordby, (2007) observed that by tank mixing two or more herbicides, the residual effect of atrazine is reduced. A combination of two herbicides and a combination of three herbicides showed significant effects ($p<0.05$) after mean separation. This could be because the additional herbicide further reduced the residual effects of atrazine.

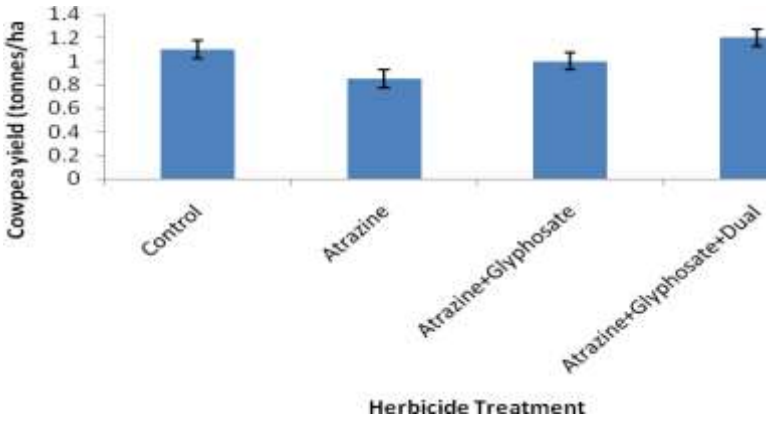

Figure 4: The effect of herbicide on cowpea yield
Vertical bars represent standard error bars of means

CONCLUSION

Germination of cowpea was not affected by the residual atrazine. Cowpea growth was not affected by the residual atrazine however; yield of cowpea was significantly affected. The control treatment had the highest pod length with the lowest pod length obtained from atrazine. A combination of three herbicides had the highest yield due to breakdown of atrazine induced by tank mixtures. Residual effects of herbicide were noted in Atrazine when applied alone and this resulted in lowest yields. Weed biomass and cowpea biomass were also not affected by the residual atrazine as the atrazine could have been leached beyond the rooting zone.

ACKNOWLEDGEMENT

The first author would like to thank the Hatcliffe Institute of Agricultural Engineering for their support during this study. This work was carried out as part of Hatcliffe Institute activities in Zimbabwe.

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Cite this Article: Mutsvandiani C, Tembo L, Kurangwa W, 2015. The effect of Herbicides on Residual Effects of Atrazine under Conservation Agriculture. Greener Journal of Agricultural Sciences, 5(2): 062-075, http://doi.org/10.15580/GJAS.2015.2.082914341.

APPENDICES

Appendix i. Cowpea germination percentage_ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr
rep stratum	2	217.3	108.6	0.83	
rep *Units*stratum					
trt	3	161.9	54.0	0.41	0.752
Residual	6	789.0	131.5		
Total	11	1168.2			

Table of means
Variate: %_germination
Grand mean 43.7

Trt	1	2	3	4
	43.6	39.6	41.9	49.5

Standard error of means

Table	trt
rep	3
d.f.	6
e.s.e.	6.62

Standard error of difference of means

Table	trt
rep	3
d.f.	6
s.e.d.	9.36

Least significant difference of means (5% level)

Table	trt
rep	3
d.f.	6
l.s.d.	22.91

Appendix ii. Cow pea pod Length_cm

.Variate: Length_cm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr
rep stratum	2	0..2450	0.1225	0.76	
rep *Units*stratum					
trt	3	2.4558	0.8186	5.11	0.043
Residual	6	0.9617	0.1603		
Total	11	3.6625			

Table of means
Variate: Length_cm
Grand mean 16.37

Trt	1	2	3	4
	17.03	15.77	16.27	16.43

Standard error of means

Table	trt
rep	3
d.f.	6
e.s.e.	6.62

Standard error of difference of means

Table	trt
rep	3
d.f.	6
s.e.d.	0.327

Least significant difference of means (5% level)

Table	trt
rep	3
d.f.	6
l.s.d.	0.800

Appendix iii. Weed fresh weight_kg_ha

.Variate: Weed fresh weight _kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr
Rep stratum					
Treatment	3	1080	360.2		
Rep. *Units* stratum					
Treatment	3	2616.5	872.0	1.07	0.441
Residual	5	4078.7	815.7		
Total	11	7775.4			

***** Information summary *****

Model term	e.f.	non-orthogonal terms
Rep stratum		
Treatment	0.111	
Rep. *Units* stratum		
Treatment	0.889	Rep

*Message the following units have large residuals.
Rep 2 *units* 2 40.8 s.e. 18.4

*****Table of means*****
Variate: Weed fresh biomass_kg
Grand mean 26.4

Treatment	1	2	3	4
	30.3	35.7	21.8	17.8

Standard error of means

Table	Treatment
rep	3
d.f.	5
e.s.e.	17.49

*** Standard error of difference of means ***

Table	Treatment
rep	3
d.f.	5
s.e.d.	24.73

*** Least significant difference of means (5% level) ***

Table	Treatment
rep	3
d.f.	5
l.s.d.	63.58

Appendix iv. Weed dry weight_ kg_ha

.Variate: Weed dry biomass_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr
Rep stratum					
Treatment	3	234.0	78.0		0.414
Residual	5	762.7	152.5		
Total	11	1524.4			

***** Information summary *****

Model term	e.f.	non-orthogonal terms
Rep stratum		
Treatment	0.111	
Rep. *Units* stratum		
Treatment	0.889	Rep

*Message the following units have large residuals.

Rep 2 *inits* 2 17.2 s.e. 8.0.

*****Table of means*****

Variate: Weed dry biomass_kg

Grand mean 26.4

Treatment	1	2	3	4
	30.3	35.7	21.8	17.8

Standard error of means

Table	Treatment
rep	3
d.f.	5
e.s.e.	7.56

*** Standard error of difference of means ***

Table	Treatment
rep	3
d.f.	5
s.e.d.	27.49

*** Least significant difference of means (5% level) ***

Table	Treatment
rep	3
d.f.	5
l.s.d.	27.49

Appendix v. Cowpea fresh biomass_kg_ha week 1

.Variate: Cowpea fresh biomass_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr
Rep stratum					
Treatment	3	2816.0	938.7		
Rep. *Units* stratum					
Treatment	3	499.3	166.43	0.17	0.913
Residual	5	4911.8	982.4		
Total	11	8227.2			

***** Information summary *****

Model term	e.f.	non-orthogonal terms
Rep stratum		
Treatment	0.111	
Rep. *Units* stratum		
Treatment	0.889	Rep

*****Table of means*****

Variate: Cowpea dry biomass_kg_1

Grand mean 144.3

Treatment	1	2	3	4
	138.6	154.7	137.7	146.2

Standard error of means

Table	Treatment
rep	3
d.f.	5
e.s.e.	19.19

*** Standard error of difference of means ***

Table	Treatment
rep	3
d.f.	5
s.e.d.	27.14

*** Least significant difference of means (5% level) ***

Table	Treatment
rep	3
d.f.	5
l.s.d.	69.77

Appendix vi. Cowpea dry biomass_kg_ha week 2

.Variate: Cowpea dry biomass_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr
Rep stratum					
Treatment	3	53947.	17982.		
Rep. *Units* stratum					
Treatment	3	24050.	8017.	0.62	0.630
Residual	5	64267.	12853.		
Total	11	142264.			

***** Information summary *****

Model term	e.f.	non-orthogonal terms
Rep stratum		
Treatment	0.111	
Rep. *Units* stratum		
Treatment	0.889	Rep

*****Table of means*****
Variate: Cowpea fresh biomass_kg_ ha
Grand mean 45.3

Treatment	1	2	3	4
	387.	520.	462.	443.

Standard error of means

Table	Treatment
rep	3
d.f.	5
e.s.e.	69.4

*** Standard error of difference of means ***

Table	Treatment
rep	3
d.f.	5
s.e.d.	98.2

*** Least significant difference of means (5% level) ***

Table	Treatment
rep	3
d.f.	5
l.s.d.	252.4

Appendix vi. Cowpea dry biomass_kg_ha week 3
Variate: Cowpea dry biomass_kg_ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr
Rep stratum					
Treatment	3	174597.	58199.		
Rep. *Units* stratum					
Treatment	3	94100.	31367.	0.21	0.882
Residual	5	730792.	146158.		
Total	11	999489.			

***** Information summary *****

Model term	e.f.	non-orthogonal terms
Rep stratum		
Treatment	0.111	
Rep. *Units* stratum		
Treatment	0.889	Rep

*****Table of means*****
Variate: Cowpea fresh biomass_kg_ week 3
Grand mean 999.

Treatment	1	2	3	4
	894.	953.	1148.	999.

Standard error of means

Table	Treatment
rep	3
d.f.	5
e.s.e.	234.1

*** Standard error of difference of means ***

Table	Treatment
rep	3
d.f.	5
s.e.d.	331.1

*** Least significant difference of means (5% level) ***

Table	Treatment
rep	3
d.f.	5
l.s.d.	851.1

Appendix vi. Cowpea dry biomass_kg week 1

.Variate: Cowpea dry biomass_kg_ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr
Rep stratum					
Treatment	3	32.73	10.91		
Rep. *Units* stratum					
Treatment	3	9.93	3.31	0.23	0.875
Residual	5	73.47	14.69		
Total	11	116.14			

***** Information summary *****

Model term	e.f.	non-orthogonal terms
Rep stratum		
Treatment	0.111	
Rep. *Units* stratum		
Treatment	0.889	Rep

*MESSAGE: the following units have large residuals.

Rep 2 * units* 2 -5.0 s.e. 2.5

*****Table of means*****

Variate: Cowpea dry biomass_kg_ha week 1

Grand mean 16.1

Treatment	1	2	3	4
	14.5	17.1	16.4	16.5

Standard error of means

Table	Treatment
rep	3
d.f.	5
e.s.e.	2.35

*** Standard error of difference of means ***

Table	Treatment
rep	3
d.f.	5
s.e.d.	3.32

*** Least significant difference of means (5% level) ***

Table	Treatment
rep	3
d.f.	5
l.s.d.	8.53

Appendix viii. Cowpea dry biomass_kg_ha week 2

.Variate: Cowpea dry biomass_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr
Rep stratum					
Treatment	3	474.9	158.3		
Rep. *Units* stratum					

Treatment	3	319.2	106.4	0.55	0.669
Residual	5	965.3	193.1		
Total	11	1759.3			

***** Information summary *****

Model term	e.f.	non-orthogonal terms
Rep stratum		
Treatment	0.111	
Rep. *Units* stratum		
Treatment	0.889	Rep

*****Table of means*****

Variate: Cowpea dry biomass_kg_ha week 2

Grand mean 16.1

Treatment	1	2	3	4
	54.9	69.9	64.4	60.5

Standard error of means

Table	Treatment
rep	3
d.f.	5
e.s.e.	8.51

*** Standard error of difference of means ***

Table	Treatment
rep	3
d.f.	5
s.e.d.	12.3

*** Least significant difference of means (5% level) ***

Table	Treatment
rep	3
d.f.	5
l.s.d.	30.93

Appendix xi. Cowpea dry biomass_kg week 3

.Variate: Cowpea dry biomass_kg_ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr
Rep stratum					
Treatment	3	2178.	726.		
Rep. *Units* stratum					
Treatment	3	613.	204.	0.13	0.940
Residual	5	8022.	1604.		
Total	11	10813.			

***** Information summary *****

Model term	e.f.	non-orthogonal terms
Rep stratum		
Treatment	0.111	
Rep. *Units* stratum		
Treatment	0.889	Rep

*****Table of means*****

Variate: Cowpea dry biomass_kg_ha week 3

Grand mean 171.

Treatment	1	2	3	4
	163.	183.	171.	166.

Standard error of means

Table	Treatment
rep	3
d.f.	5
e.s.e.	8.51

*** Standard error of difference of means ***

Table	Treatment
rep	3
d.f.	5
s.e.d.	24.5

*** Least significant difference of means (5% level) ***

Table	Treatment
rep	3
d.f.	5
l.s.d.	89.2

Appendix x. Cowpea yield_kg

.Variate: Cowpea yield_kg_ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr
Rep stratum	2	13522.	6761.	1.37	
Rep. *Units* stratum					
Treatment	3	130973.	43658.	8.82	0.013
Residual	6	29698.	4950.		
Total	11	174193.			

*****Table of means*****

Variate: Cowpea yield_kg

Grand mean 1066.

Treatment	1	2	3	4
	163.	183.	171.	166.

Standard error of means

Table	Treatment
rep	3
d.f.	5
e.s.e.	40.6

*** Standard error of difference of means ***

Table	Treatment
rep	3
d.f.	5
s.e.d.	57.4

***** Stratum errors and coefficients of variation *****

.Variate: Cowpea yield_kg_ha

Stratum	d.f.	s.e.	c.v %
Rep	2	41.1.	3.9

*** Least significant difference of means (5% level) ***

Table	Treatment
rep	3
d.f.	6
l.s.d.	140.6