

Role of Variety and Fertilizer Practices on Cowpeas (*Vigna unguiculata*) Yield and Field Incidence of the Parasitic Weed *Alectra vogelii* (Benth) in Central Malawi

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Abstract

Grain legumes are an important component of the food systems in Malawi. The parasitic legume witchweed species *Alectra vogelii* (Benth) is among the problem pests with serious infestations in groundnuts (*Arachis hypogea*), soybeans (*Glycine max*), cowpeas (*Vigna unguiculata*) and other legumes. A study was conducted in 2013/14 and '14/15 seasons to evaluate the effects of three cowpea varieties (IT82E-16, Sudan 1 and *Alectra*-resistant Mkanakaufi) and fertilizer practices (no fertilizer applied, 5 t ha⁻¹ cattle manure and 100 kg ha⁻¹ of inorganic 23:21:0+4S on cowpea grain yield, yield components and *Alectra* emergence at three sites in central Malawi. Cowpea grain yields ranged 400-2400 kg ha⁻¹. There were significant ($P < 0.05$) variety effects on yield in 4 of 6 site-years, with variety IT82-16 consistently giving the highest yields (range 1200-2400 kg ha⁻¹). There were significant variety effects on *A. vogelii* emergence with Mkanakaufi having no *Alectra* throughout. Application of cattle manure strongly suppressed *A. vogelii* in 6 site-years all at 60 days after planting, while inorganic fertilizer suppressed *Alectra* in 3 of the 6 site-years. Cattle significantly but marginally (about 250 kg ha⁻¹) increased yield in 2 of the 6 site-years. The results show potential to suppress *A. vogelii* with cattle manure application. However, further studies are required to understand the causes of the limited yield response under manure or fertilizer application to make the practices attractive to farmers. More variety improvement studies to produce a range of varieties with better local adaptability and response to fertility amendments are recommended.

1. Introduction

Maize (*Zea mays* L.) is the staple food and predominant crop in the farming systems in Malawi. Grain legumes are also important and complement cereals in terms of nutrition and rotation benefits. In 2013/14 season grain legumes (pulses and groundnuts [*Arachis hypogea*]) were grown on a total 0.98 M ha or 65% of the maize land (MoAFS, 2012). The relatively large area of grain legumes offers opportunity for complementary integration of maize and legumes in cropping systems. Grain legumes cropping systems are complimentary to staple cereals in many ways. Legumes are important for their enrichment of soil nitrogen through biological nitrogen fixation (Nyemba & Dakora, 2010; Ojiem et al., 2000, Myaka et al., 2006), high protein content, edible oil, and animal feed. In Malawi, legumes have been widely promoted most notably through including the national Farm Input Subsidy Programme (FISP), which included seeds of grain legumes (MoAFS, 2007; Dorward et al., 2011; MoAIWD, 2012). Among the legumes, cowpeas (*Vigna unguiculata*) are one of the important crops for similar reasons. Cowpeas contain 22-32% protein (Neil et al., 1992), are adaptable to drought (Hall, 2004), can be used as animal fodder, and have suitability as cover crops in conservation agriculture systems (Mupangwa et al., 2012). In Burkina Faso, Bado et al. (2006) reported that cowpeas accumulated 2.5-3.4 t ha⁻¹ of stover containing 50 to 115 kg ha⁻¹ N of which 52-56% was derived from the atmosphere while in Malawi, Magulu and Kabambe (2013) reported 1.5 to 3 t ha⁻¹ of cowpea stover with 2.4% N content.

Among other production constraints, many legumes are prone to attack by the parasitic weed species *Alectra vogelii* of the family Orobanchaceae, which causes serious losses. The weed has been reported in many parts of Malawi (Riches & Shaxson, 1993; Kabambe et al., 2014; CABI, 2017). Yield losses of up to 15-100% have been reported in groundnut, soybean (*Glycine max*) and bambara (*Vigna subterranea* L.) (Lagoke, 1989; Beck, 1989; Kureh et al., 1999). For cowpeas, Lagoke et al. (1993) reported yield losses of 41%, while Riches (1989)

reported losses of 80-100 in a susceptible cultivar in Botswana. In Tanzania, Mbwaga et al. (2000) reported yield losses of 50%.

In Malawi *Striga asiatica*, another parasitic weed of the same family is also a serious constraint in the staple cereal maize, such that many fields experience the two species simultaneously. There have been extensive reviews on control methods on these witchweeds (Parker & Riches, 1993; Parker, 2012; Rubiales & Fernandez-Aparicio, 2012; Joel et al., 2013). Some of the control approaches for the witchweed *A. vogelii* considered feasible for smallholder farmers include use of trap crops such as dolichos bean (*Lablab purpureus* [L.] Sweet), cotton (*Gossypium hirsutum* L.), okra (*Hibiscus esculentus* L.), pea (*Pisum sativum* L.) and faba bean (*Vicia faba* L.) (Parker & Riches, 1993). While a resistant cowpea variety was released in Malawi in 2010 (Mviha et al., 2011; Kabambe et al., 2014), this is only one step in integrated management. Several resistant varieties are needed to meet the various biotic and abiotic production constraints in addition to satisfying diverse end-user preferences. Non-variety management approaches are therefore equally required for integrated management. Karanja et al. (2012) reported that cattle manure at 5 t ha⁻¹ suppressed *A. vogelii* and improved yield of cowpeas, but effects depended on cowpea variety. Akande et al. (2008) reported that complementary use of Ogun rock phosphate and cow dung increased yields of cowpea in Nigeria. Much research on fertility fertilizer application has been done in *S. asiatica*, which has similar biology to *A. vogelii*. For example, in Malawi, Kabambe (1991) reported that cattle manure and fertilizer application controlled *Striga asiatica* in maize. In *S. asiatica*, nitrogen is known to reduce germination and emergence through reduction of stimulant production by host (Raju et al., 1990; Okonkwo, 1991). The ammonium form of N is particularly injurious to *Striga* seeds and suppressive to germination and radical elongation (Pesch & Pieterse, 1982; Okonkwo, 1991; Chechin & Press, 1993; Eplee & Norris, 1994). A study was therefore conducted in 2013-14 and 2014-15 seasons to evaluate the combined role of cowpea genotype and fertilizer practices (cattle manure and inorganic fertilizer application) on cowpea productivity and *Alectra* field emergence.

2. Materials and Methods

2.1 Trial Design, Treatment Factors and Sites

The field trial was a 3 × 3 factorial experiment with three varieties (IT82E-16, Sudan 1 and Mkanakaufiti) and three fertilizer practices (no application, 5 t/ha cattle manure, and 100 kg/ha 23:21:0:4S) as factors. The 23:21:0:4S is a compound fertilizer available in Malawi and recommended for basal dressing in maize and soybeans, however, there is no fertilizer recommendation for cowpea production in Malawi (MoAFS, 2012). The purpose of the 23:21:0:4S treatment was to compare manure effects and an inorganic, non-ammonia source of fertilizer in common use. The 5 t ha⁻¹ of manure has been shown to suppress *Alectra* and improve yields in cowpea (Karanja et al., 2012). The same rate has also been shown to improve yields in maize (Mloza-Banda & Kabambe, 2014). The fertility amendments were studied using the application methods being used by farmers in order to evaluate the practice as a package. Varieties IT82E-16 and Sudan 1 are released, semi-erect with 59-74 days maturity period and yield potential of 2.0 t ha⁻¹ (Mviha, 2011, MoAFS, 2012). Mkanakaufiti is also a released variety, resistant to *A. vogelii*, spreading type, 70-80 days maturity and yield potential of 2.3 t ha⁻¹ (Kabambe et al., 2014; MoAFS, 2012). The trial sites were Bunda College, Mkwinda (near Bunda College, Lilongwe District) and Chioshya EPA in Mchinji in 2013-14 and Bunda, Chioshya and Mtunthama (Kasungu district) in 2014/15 season. All sites had a history *Alectra vogelii* pressure. The trial design was randomized complete block with four replicates at Bunda and 6 replicated on farmers fields. A replicate was hosted on a separate farmers field. At each site the cattle manure was sourced from one farmer but used by the rest of the farmers including at Bunda College where the manure came from the College farm. All sites are in the mid-altitude agro-ecological zone of Malawi with a mean annual rainfall of 875 mm (MoAFS, 2012). Table 1 gives the mean monthly rainfall planting and planting dates for the sites. The rainfall data for the Mkwinda is the same as for Bunda, as it was an on-farm site near Bunda. The rainfall in year one rainfall was in normal range while in year two of study rainfall was 50-60% lower than year average.

Table 1. Mean monthly rainfall (mm), altitude (masl) and GPS for the trial sites in 2013/14 and 14/15 seasons

	2013/14 season			2014/15 season		
	Bunda	Mkwinda	Chioshya	Bunda	Chioshya	Mtunthama
Month/Planting date	8.1.14	20.1.14	27.12.13	5.1.15	26.12.14	3.12.14
GPS	S14.15035° E33.78753°	S14.15035° E33.78753°	S13.7993° E33.1954°	S14.15035° E33.78753°	S13.7993° E33.1954°	S14.7993° E33.6346°
Altitude masl	1162	1128	1078	1162	1078	1165
October	17.5	17.5	0	0	0	0
November	39.3	39.3	0	28.4	8.2	42.4
December	276	276	101.6	11.5	121.4	146
January	273.8	273.8	330.6	226.9	138.1	156.4
February	305	305	206.9	107.5	164.9	120.7
March	132	132	90	103	122	67.5
April	55.5	55.5	51	63.4	57	59.5
May	5.5	5.5	0	18.9	0	21
Total	1104.6	1104.6	780.1	549.2	611.6	613.1

2.2 Plots Sizes, Trial Management, Data Collected and Analysis

The experimental crop was planted in plots of 4 with raised ridges each 4.0 m in length and 0.75 m apart. Two seeds of cowpeas were planted at 20 cm apart, giving an expected stand count of 13.3 plants m⁻². The manure was applied in a band made by splitting the ridge to 20 cm depth and then rebuilding it, while the inorganic fertilizer was applied in a shallow band of 10 cm on the side of the ridge and covered. All cowpea or *A. vogelii* data was collected from the two middle rows giving a net plot size of 6 m². Data collected for evaluation were cowpea grain yield (adjusted to 10.0% moisture), pod number, plant counts and *A. vogelii* counts. All insect and aphid pests were controlled by spraying according to recommendations (MoAFS, 2012). Data were analysed on site basis according to the analysis of variance procedure using the Genstat 16 package. Treatment effects were declared significant at $P \leq 0.05$. Comparisons between means were done using the least significant difference, LSD at $t \leq 0.05$.

3. Results

3.1 Variety Effects on Cowpea Yield, Yield Components and Alectra Emergence

In the 2013/14 season there were significant variety effects on cowpea harvest count (plants m⁻²) at Bunda only (Table 2) and not at Mkwinda (mean = 8.96) and Chioshya (mean = 9.85). In the second season, significant variety effects on harvest count were observed at Bunda and Mtunthama (Table 2) and not at Chioshya (mean 12.78 plants m⁻²). There were also significant variety effects on pods plant⁻¹ at Bunda (Table 1) and not Mkwinda (mean 5.79). Data for Chioshya was not available. In the second season, significant variety effects on pod plant⁻¹ were observed also at Bunda only. Mean pod plant⁻¹ were 12.29 and 12.56 at Mtunthama and Chioshya, respectively. Mkanakaufiti generally performed poorly.

Table 2. Effect of variety on cowpea plant establishment and pods per plant at Bunda, Mtunthama and Chioshya, 2013/14 and 2014/15 season

Variety/Site/Season	Plants at harvest m ⁻²			Pods plant ⁻¹	
	Bunda 2013/14	Bunda 2014/15	Mtunthama 2014/15	Bunda 2013/14	Bunda 2014/15
IT82E-16	10.57	11.79	12.86	9.59	20.28
Sudan1	11.97	12.63	12.80	10.96	20.73
Mkanakaufiti	12.85	13.04	11.80	6.55	11.86
Mean	11.80	12.48	12.48	9.03	17.62
F prob	<0.001	0.026	0.006	0.001	0.01
LSD _{0.05}	1.01	0.89	0.70	2.10	5.11

The effects of cowpea variety on grain yield are shown in Table 3. There were significant variety effects in 4 of the 6 site-years. No significant differences were observed in 2013/14 at Mkwinda (mean 679 kg ha⁻¹) and Chioshya (mean 2202 kg ha⁻¹). In all the cases Mkanakaufiti gave the lowest yields. High yields of 2000 to 2400 kg ha⁻¹ were observed at Mtunthama and Bunda in 2014/15. At all sites and in both seasons there were no

significant differences of variety \times fertilizer package interactions on cowpea data. Interestingly, yields in second year were about 2 t ha⁻¹ and above, yet the season experienced low rainfall in the range 549 to 613 mm.

There were significant cowpea variety effects on *A. vogelii* emergence effects at 40 and 60 days after planting at all sites (Tables 4 and 5). There was consistently no *Alectra* observed on Mkanakaufiti at 40 or 60 DAP. The results confirm the resistance of Mkanakaufiti to *Alectra* (Kabambe et al., 2014).

Table 3. Effect of variety cowpea grain yield kg ha⁻¹ in 2013/14 and 204/15 seasons

Variety/Site	Site and season			
	Bunda 2013/14	Bunda 2014/15	Chioshya 2014/15	Mtunthama 2014/15
IT82E-16	1203	2481	2186	2071
Sudan 1	1413	2362	2002	2001
Mkanakaufiti	947	2068	1768	1676
Mean	1187	2304	1985	1916
F prob	0.007	0.010	0.007	0.009
LSD _{0.05}	277	128	252	262

Table 4. Effect of variety on *Alectra* counts at 40 and 60 days after planting (DAP) in 2013/14

Variety/Site	<i>Alectra</i> counts m ⁻² —40 days			<i>Alectra</i> counts m ⁻² —60 days		
	Bunda	Mkwinda	Chioshya	Bunda	Mkwinda	Chioshya
IT82E-16	0.24	0.22	0.51	1.78	1.58	2.18
Sudan1	0.65	0.21	0.97	2.12	1.79	2.79
Mkanakaufiti	0.0	0.0	0.0	0.0	0.0	0.0
Mean	0.30	0.14	0.50	1.30	1.13	1.66
F prob	<0.001	<0.001	0.07	0.001	<0.001	<0.001
LSD _{0.05}	0.33	0.12	0.84	0.85	0.93	1.09

Table 5. Effect of variety on *Alectra* counts at 40 and 60 days after planting (DAP) in 2014/15

Variety/Site	<i>Alectra</i> counts m ⁻² —40 days			<i>Alectra</i> counts m ⁻² —60 days		
	Bunda	Chioshya	Mtunthama	Bunda	Chioshya	Mtunthama
IT82E-16	0.5	0.93	1.2	2.01	5.5	3.6
Sudan1	0.9	1.03	1.1	2.07	6.2	4.6
Mkanakaufiti	0	0.0	0	0	0	0
Mean	0.4	6.65	0.74	1.4	3.9	2.7
F prob	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
LSD _{0.05}	0.15	0.39	0.48	0.41	2.4	0.014

3.2 Effects of Fertilizer Practices on Harvest Count, Pods Plant⁻¹, Grain Yield and *Alectra* Emergence

Fertilizer practice as factor did not significantly affect cowpea harvest count in both seasons except at Chioshya where manure application suppressed plant stand to 8.72 plants m⁻² compared to 10.97 plants m⁻² with no amendment. There were also fertilizer package effects on pods plant⁻¹ only at Bunda in 2014/15. The inorganic fertilizer package of 23:21:0+4S had lowest pods plant⁻¹ of 15.4, compared to 18.3 or 19.15 for no amendment and manure application. No significant interaction effects were observed.

The effects of fertilizer packages on grain yield are shown in Table 6. There were significant fertilizer practice effects on yield in 3 of the 6 site-years. At Mkwinda (2013/14) and Mtunthama (2014/15) 20:21:0+4S gave the lowest yields. Notably cattle manure significantly increased yield at Mtunthama and Chioshya, even through by margins of only 250 kg ha⁻¹.

Table 6. Effect of fertilizer package on cowpea grain yield (kg ha⁻¹) in 2013/14 and 204/15 seasons

Fertilizer	Site and season		
	Mkwinda 2013/14	Mtunthama 2014/15	Chioshya 2014/15
None	698	1705	1764
5t ha ⁻¹ cattle manure	871	2001	2060
23:21:0+4S (100 kg ha ⁻¹)	468	1676	2131
Mean	679	1794	1985
F Prob	0.028	0.023	0.013
LSD _{0.05}	290	262	252

In 2013/14 at 40 DAP manure application significantly suppressed *Alectra* emergence at Mkwinda only. At 60 DAP manure application significantly suppressed *Alectra* numbers at all three sites. *Alectra* emergence (Table 7) was very low at 40 days after planting, DAP. In 2014/15 manure application significantly suppressed *Alectra* at all sites and counts (Table 8). It is also of interest to note that yields were highest at Chioshya, an on-farm site with high *Alectra* incidence.

Table 7. Effect of fertilizer package on *Alectra* counts at 40 and 60 days after planting (DAP) in 2013/14 season

Fertilizer/Site	<i>Alectra</i> counts m ⁻² —40 days			<i>Alectra</i> counts ⁻² —60 days		
	Bunda	Mkwinda	Chioshya	Bunda	Mkwinda	Chioshya
None	0.38	0.32	0.54	1.69	2.17	2.54
5 t ha ⁻¹ cattle manure	0.29	0.04	0.54	0.36	0.18	0.53
23:21:0+4S (100 kg ha ⁻¹)	0.22	0.07	0.40	1.85	1.04	1.86
F Prob	0.61	<0.001	0.93	0.002	<0.001	0.02
LSD	0.33	0.12	0.84	0.85	0.93	1.09

Table 8. Effect of fertilizer package on *Alectra* counts at 40 and 60 days after planting (DAP) in 2014/15 season

Fertilizer/Site	<i>Alectra</i> counts m ⁻² —40 days			<i>Alectra</i> counts ⁻² —60 days		
	Bunda	Chioshya	Mtunthama	Bunda	Chioshya	Mtunthama
None	0.6	0.82	1.1	2.2	5.9	4.3
5 t ha ⁻² cattle manure	0.2	0.25	0.1	0.5	1.1	0.8
23:21:0+4S (100 kg ha ⁻¹)	0.4	0.85	1.0	1.5	4.8	3.2
F Prob	0.029	0.009	<0.001	0.002	<0.001	<0.001
LSD	0.15	0.39	0.48	0.41	2.4	1.4

There was significant variety × fertility amendment effect on *Alectra* emergence at 40 and 60 DAP at Mkwinda in 2013/14 and Mtunthama in 2014/15 (Table 9). In both cases the interaction is arising from non-emergence of *Alectra* at all fertilizer practices, and also the strong suppression of *Alectra* by manure across all varieties, while there was relatively high *Alectra* in the other varieties and fertilizer practices. The highlight of the results is that there was no *Alectra* emergence on Mkanakaufiti and strong suppression of *Alectra* by manure on all count dates in both seasons.

Table 9. Effect of variety × fertilizer package on *Alectra* emergence (m⁻²) at 60 days after planting at Mkwinda (2013/14) and Mtunthama (2014/15)

Variety/Fertilizer package	Mkwinda 2013/14			Mtunthama 2014/15		
	No fertilizer	5 t ha ⁻¹ manure	100 kg ha ⁻¹ 23:21:0	No fertilizer	5 t ha ⁻¹ manure	100 kg ha ⁻¹ 23:21:0
	----- <i>Alectra</i> count m ⁻² -----					
IT82E-16	3.46	0.25	1.04	5.92	1.06	3.81
Sudan 1	3.0	0.2	2.08	7.0	1.19	5.64
Mkanakaufiti	0.04	0	0	0	0	0
LSD (0.05)	1.61			2.64		

4. Discussion

4.1 How Does *Alectra*-Resistant Variety Maintain Its Resistance Without Yield Advantage?

The yield ranges in the studies are similar to those of Kabambe et al. (2014) who reported yield ranges of 1-2.5 to tha^{-1} for the same varieties. The results show superiority in yield performance of the non-resistant varieties compared to the resistant varieties. The lack of yield advantage by Mkanakaufiti, while it demonstrated resistance to *Alectra* is disappointing, but consistent previous reports (Kabambe et al., 2014). Karanja et al. (2013) also showed that resistant germplasm to *Alectra* did not always give high yields, but provided source of germplasm for improvement. Genotype resistance remains an important trait in integrated management where it would serve to reduce *Alectra* seed build up in rotation systems as well as other non-variety interventions, which could include manure, mulching or herbicides. In a recent screen house study involving all three cowpea varieties with and without *Alectra* infection, (Phiri et al., 2018) reported no significant ($P > 0.05$) variety or infection \times variety interaction effect on cowpea root and shoot dry weight at 12 weeks, in support of these results whereby the resistance of Mkanakaufiti did not translate to better growth. However, in the same study, the authors reported significant *Alectra* inoculation and variety effect on dry root mass at 5 weeks only, which showed that infected cowpeas gave higher dry root mass and Mkanakaufiti gave the lowest root mass. Their results were attributed to weight of young *Alectra* plants on the roots of susceptible cowpea varieties. In a separate study, the authors reported that Mkanakaufi delayed but eventually supported germination of *Alectra*, suggesting refusal of further development as a mechanism. Previous studies have reported yields losses in cowpeas (Lagoke et al., 1993; Riches, 1989; Bagnall-Oakely et al., 1991) and other legumes (Lagoke, 1989; Beck, 1989; Kureh et al., 1999) thus it would be expected of resistant varieties to demonstrate a yield advantage especially under poor on-farm sites. Mugabe (1983) reported that yield in cowpea was mediated through delayed start of flowering, reduction in number of pods, and reduced mass of pods and grain. Alonge et al. (2001) reported the negative effects of *Alectra* on grain yield, grain protein content and total soluble carbohydrates depended on date of planting. This suggests that environmental factors such as water, temperature and soil fertility have part on the impact of *Alectra*. However, some varieties can be tolerant, as is likely with the two non-*Alectra* resistant varieties can be considered tolerant in view of repeated nature of results. A lack of variety \times fertilizer interaction on grain yield in all site-years shows that while IT82E-16 is well adapted and high yielding, it is not responsive to fertility amendments. Hence breeding activities are required to develop genotypes that can respond to fertility improvements. At the time of its release, Mkanakaufiti was equal in yield to these varieties while possessing strong resistance.

4.2 How Does Cattle Manure Suppress *Alectra* Without Consistent Yield Advantage?

Alectra emergence was higher at 60 DAP and the impact of fertilizer practices, particularly cattle manure, was more pronounced (Tables 7 and 8). The suppression of *Alectra* by cattle manure application conforms with many previous reports with Orobanchaceae family. In *S. hermonthica* or *S. asiatica*, which have similar host-parasite biology, nitrogen, particularly the ammonium form, has been reported to suppress germination and radicle elongation (Pesch & Pieterse, 1982; Okonkwo 1991; Chechin & Press, 1993; Eplee & Norris, 1994). Use of both organic and inorganic fertilizer amendments has been reported to increase yields in cereals and cowpeas (Kabambe, 1991; Karanja et al., 2012; Akande et al., 2008). In this study fertilizer package effects were inconsistent, with significant effects observed in three of the six site-years (Table 6). The variation in yield advantage in study is thus not surprising. In cowpea Karanja et al. (2012) showed that that manure application increased yield of some varieties, and not others. Further, there is no fertilizer or manure recommendation for improved cowpea production in Malawi, suggesting responses to fertility amendments are rare. Farmers are therefore unlikely to take up manure application for the sake of *Alectra* control alone, calling for need to explore innovative cropping systems which include crops that can benefit from the fertility amendments in association or subsequent crops with cowpeas. Further studies are required to understand the specific reasons for lack of yield response to manure and P containing fertilizer, considering literature elsewhere which recommends fertility amendments. For example, Vanderborgh and Baudin (2001) recommended P fertilization to increase cowpea yields at an N:P:K ratio of 1:2:1.

5. Conclusion

Alectra-resistant Mkanakaufiti remains strongly resistant while the two other released varieties showed good tolerance to *Alectra*. Breeding work should continue so that more varieties with diverse traits for farmer and end-user preferences are available. The use of cattle manure at 5 t ha^{-1} had directive suppressive effects on *Alectra* emergence, with small and inconsistent yield benefits. The combined suppression of *Alectra* through genotype resistance and manure would form a strong base for reducing *Alectra* seed build in the soil in its integrated

management. More germplasm should be evaluated to come up with varieties that can respond to fertility amendments hence provide incentive for farmer adoption.

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