UNRAVELING SEED DORMANCY AND HOST SPECIFICITY OF *ALECTRA VOGELII* IN MALAWI

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A R T I C L E   I N F O

A B S T R A C T

Parasitic angiosperm *Alectra vogelii* Benth is a growing problem in Malawi, particularly with the current emphasis on legume crops. Therefore, a pot experiment was conducted in Lilongwe, Malawi to evaluate the effects of site, *A. vogelii* dormancy-breaking period on Mkanakaufiti and IT82E-16 cowpea varieties. Varieties of cowpea were grown in *A. vogelii*-infested pots sourced from three agroecological zones and subjected to varied dormancy-breaking periods. The experiment was arranged in a Randomized Complete Block Design and replicated four times. The study revealed that dormancy breaking had impacts depending on the *A. vogelii* source. However, the *Alectra* source affected the *A. vogelii* shoot counts and cowpea grain weight. Neno-Manyenye collections had a higher incidence without induced dormancy breaking periods while Lilongwe-Kamowa, and Salima-Matumba collections had a high incidence after the dormancy-breaking period. Late infestation (at 119 to 149 days after planting) on resistant Mkanakaufiti cowpea variety by *A. vogelii* collections used indicated apparent strain variability of collections used. The results confirmed the delayed resistance mechanism of Mkanakaufiti against *A. vogelii*. Nevertheless, the variety reactions on the parasitic weed depends on suitability, compatibility, and specificity, although some resistant genotypes tend to lose the resistance mechanism with time. *A. vogelii* seeds organic carbon % varied (4.87±1.73 to 9.13±0.95) from the three agroecological zones which signified the collections' variability due to warmer temperatures, relative humidity, and crop husbandry practices under long-term conditions. Therefore, screening efforts for resistance or evaluation of agronomic options to suppress the weed should be intensified.

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INTRODUCTION

Vigna unguiculata (L.) Walp (cowpea) is a common crop grown by smallholder farmers in Malawi (Kabambe et al., 2014; MoAFS, 2020). The crop is useful as a rotational cover crop (Somenahally et al., 2018; Bybee-Finley et al., 2022) as it fixes nitrogen (Munjonji et al., 2018; Namatsheve et al., 2020) in their nodules once adequate phosphorus is available in the soil which later

leaches into the soil, thereby, meeting a cash crop's nitrogen needs. The crop provides important nutrients for both humans and animals through seeds or leaves which accumulate higher protein, vitamin, and mineral contents (Eziz et al., 2017). Significantly, cowpea is a drought-tolerant crop (Gomes et al., 2020) which makes it valuable in rain-fed agriculture or non-irrigated fallow fields.

Cowpeas are commonly attacked by *Alectra vogelii* (Benth) which is predominant in Africa, where yield reduction can reach 80 to 100 % on susceptible genotypes (CABI, 2017; Phiri et al., 2023). The parasitic weed associates with low soil fertility (Lambers and Oliveira, 2019) unreliable rainfall, and high temperatures (Zitta et al., 2014; Zagorchev et al., 2021). A successful attachment of host-parasite occurs only when the three conditions illustrated in Figure 1 interact.
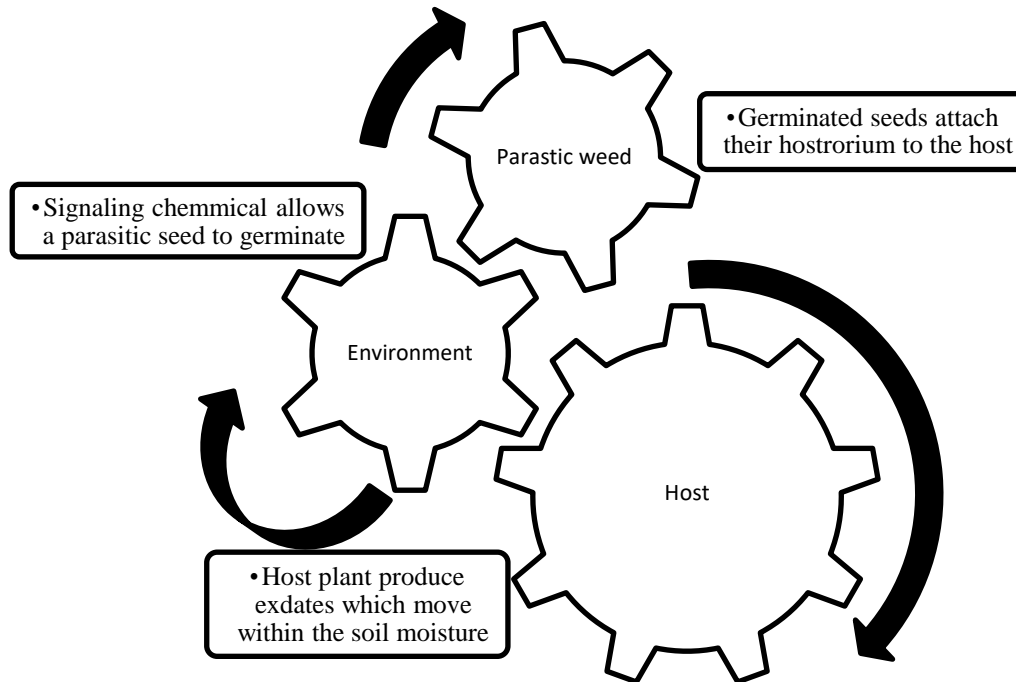

Figure 1: Cowpea -*Alectra vogelii* (Host-parasite) interaction.

A. vogelii is becoming a serious threat in several countries in East, Central, and Southern Africa (Fernández-Aparicio et al., 2020). The parasitic weeds are rather difficult to control because they produce a high number of seeds, and adaptation or dormancy mechanisms, permit the seeds to stay alive in the soil for several years (Zwanenburg et al., 2016; Qasem, 2019). Seeds of *A. vogelii* are dormant and require a period of after-ripening followed by conditioning in a warm, moist environment before responding to germination stimulants (CABI, 2017). After-ripening period on *A. vogelii*, seeds differs due to temperature variability as in hotter areas it is short as compared to cool environments (Holzner and Numata, 2013). Some of the postulated changes during the period are various structural and metabolic changes in the seed coat associated with increased softening of the seed coat making it more permeable to water, increased signaling enzymes, and protein changes (Meimoun et al., 2014). On the other hand, the embryo may occur an increase in respiratory substrate levels (CABI, 2017). After this phase, the seeds can germinate within 5 days with the availability of a suitable stimulant such as alectro or strigolatone to the dry seed at 28-30°C (Brun et al., 2018).

Before the parasitic seed can respond to them, it also requires a period of conditioning subsequently to after-ripening (Ueno et al., 2014; CABI, 2017). The stage allows the leaching of germination inhibitors which probably increases the permeability of the seed coat and changes in level of activity (Karanja et al*.,* 2013; Qasem, 2019). However, the duration of conditioning depends on factors such as temperature, origin, and age of the seeds, and the conditioning period of *A. vogelii* collection ranges from several days up to weeks with a specific temperature of 23°C (Meimoun et al., 2014). However, lengthy periods of imbibition of *Alectra* seed in water, in the absence of stimulants do not induce the wet dormancy characteristic which commonly occurs in *Striga* seeds (CABI, 2017; Phiri et al., 2023). Several studies have been undertaken to find the effects of

Alectra and *Striga* sourced from different regions and countries on their reaction to cowpea, common bean, soybean, groundnut, flax, chickpea, pigeon peas, and other legume crops (Mwaipopo, 2014; Phiri et al., 2019; Kabambe and Bokosi, 2020). However, no studies have been done on *Alectra vogelii* sourced from a wide range of agroecological zones and dormancy-breaking periods within Malawi. The study aimed at evaluating the effects of collection site and dormancy breaking period on *A. vogelii* reaction on the variety effect and it was hypothesized that variation on the *Alectra* collection, dormancy breaking period by variety effect could occur.

MATERIALS AND METHODS
Experimental site and *Alectra* collection sites
Alectra-host interaction study was conducted in a well-ventilated plastic greenhouse during the warm dry season for 160 days at Crop and Soil Sciences Students' Research Farm. The site is located at 14°35' S, 33°50' E, with an elevation of 1200 meters above sea level, in Lilongwe, Malawi (Phiri et al., 2019). Mature *Alectra* plants with ripened capsules of *Alectra* were uprooted and packed in A2 envelope papers (Kabambe and Drennan, 2005). The *Alectra* seeds were collected from Dedza-Nyombe, Ntchisi-Chimanjamanja, Lilongwe-Kamowa, Salima-Matumba, and Neno-Manyenye districts and Table 1 presents *A. vogelii* collection sites, a global positioning system, elevation, and host crops on which the collections were made. Depending on the readiness of the host crop, the collection was in phases because in Neno crop matures earlier than all the four districts, thereby creating a gap difference in the collection period. Immediately after *Alectra* collections from each site, the collections were sun-dried for 0, 10, 20, and 30 days to break dormancy. The wide range of dormancy breaking periods and *Alectra* source was to achieve an after-ripening period and to see if required or not. *Alectra* sources were hypothesized with different environmental conditions, soil status, crop management practices, and weather parameters. This could probably define the variability of *Alectra* collection on their effects on the two cowpea varieties. Thereafter, *A. vogelii* seeds were manually threshed by hand and the seeds were sieved by passing them through a sieve of 125-micron openings. Later on, the inoculum was stored at room temperature, approximately at 26°C in plastic bottles (Kabambe and Drennan, 2005; Phiri et al., 2018).

Experimental set-up
There were one hundred and sixty (160) plastic pots with a uniform diameter and depth of 22 and 20 centimeters, respectively. The pots were filled with sandy loamy soil sourced from the Bunda forest. The forest soil was chosen to prevent *Alectra* contaminations. Approximately 1500 (0.015 g) *A. vogelii* seeds were inoculated per pot after mixing with fine sandy and coarse sandy soil (Kabambe and Drennan, 2005; Phiri et al., 2018; Singh, 2020). However, the high amount of *Alectra* seeds does not guarantee germination because some could be dead, immature and at times irrigation might wash the seed downwards limiting their germination. Then, four seeds of the two selected cowpea varieties were planted per pot and thinned to three, one week after planting (WAP), representing an experimental unit. The plants were staked at 9 WAP. Irrigation was done on daily basis for each variety and it was done until the two varieties reached their physiological maturity. There was no application of any kind of fertilizer or manure to the pots. All weeds, except *A. vogelii* were manually uprooted throughout the growing period. At 160 days after sowing (DAS), cowpea samples were uprooted gently using a hand trowel and their roots were washed thoroughly. Then shoot weights were taken followed by oven drying for 24 hours at 70°C and reweighed.

There were three experimental factors as follows:- variety (V): Mkanakaufiti and IT82E-16, *A. vogelii* source (AS): Dedza-Nyombe, Ntchisi-Chimanjamanja, Lilongwe-Kamowa, Salima-Matumba and Neno-Manyenye, and dormancy-breaking period (DB): 0, 10, 20, 30 days of sun drying of *Alectra* collections. A 2×4×5 factorial treatment combination was arranged in a Randomized Complete Block Design (RCBD) and replicated four times.

Data collection
Days to first *Alectra* emergence per pot, periodic *Alectra* shoot counts at 7, 8, 9, 10, 11, and 12 WAP per pot, number of dead *Alectra* shoots per pot, *Alectra* fresh and dry biomass at harvest (g) per pot data were collected.

A. vigour ratings were done at harvest using *Striga* rating scale adopted from Tignere (2010) and Phiri (2018), as narrated below with some modifications:-
0 = No emerged *Alectra* plant
1 = Average height of *Alectra* plants <5 cm.
2 = Average height 5-10 cm.
3 = Average height 10-15 cm.
4 = Average height 15-21 cm.
5 = Average height >21 cm.

Cowpea data recorded per pot were crop fresh and dry biomass at harvest (g), number of pods, pod weight (g), and grain weight (g).

Organic carbon percentage determination in *Alectra* seed

Walkley-Black Wet Oxidation Method described by Faina et al. (2012) and Khoshnaw and Esmail (2020) was used at the Soil Science Laboratory in the Department of Crop and Soil Sciences to determine the organic carbon content in *Alectra* seeds from all five sites as a composite sample in each site. However, no ANOVA was done on organic carbon (%) as only one site collections were available and triplet sampling was done per site. The organic carbon percentage in *Alectra* seed was calculated using the formulae below:

$$\text{Organic carbon } \% = \frac{(\text{Blank} - \text{Sample}) \times 0.5 \times 1.3 \times 100}{\text{Alectra seed sample weight}}$$

Nitrogen percentage determination and density (g/cm^3) in *Alectra* seed

George, (2023) macro Kjeldahl method was employed to determine nitrogen in *Alectra vogelii* seeds from selected sites. *Alectra* seed weight was measured in 27cm^3 vial and its density was determined. However, ANOVA was not conducted due to single-site collections; triplet sampling was performed for nitrogen, *Alectra* weight, and density.

Statistical analysis

GenStat® 18 Edition (VSN International, Hemel Hempstead, UK) was used to perform analyses of variance (ANOVA). Differences between means of significant variables were separated using a least significant difference (LSD) at 5% and 10% level of significance for crop and *Alectra* data, respectively due to high variability on the data. However, all data sets which violated ANOVA normality assumption were analysed after the square root transformation of the data $[(x +0.5)^{0.5}]$ (Rana and Kumar, 2014; Phiri et al., 2019).

RESULTS

ANOVA Summary for days to first *Alectra* emergence (DFAE) and *Alectra* shoot counts

Variety × dormancy-breaking period and *Alectra* source × dormancy-breaking period interaction effects significantly affected days to first *Alectra* emergence. On the other hand, variety × *Alectra* source, *Alectra* source × dormancy-breaking period, and variety × *Alectra* source × dormancy-breaking period interactions significantly ($p>0.1$) affected *Alectra* shoot counts at 9,

10, and 11 WAP (Table 2). However, on days to the first *Alectra* emergence, *Alectra* shoot counts, dead *Alectra* shoot counts, and *Alectra* vigour score were significantly affected by varietal effects. On the other hand, *Alectra* shoots counts at 9 and 10 WAP was significantly affected by *Alectra* source (Table 2).

Interaction effects for days to first *Alectra* emergence

The results revealed that dormancy-breaking period × cowpea variety interaction was significant on days to the first *Alectra* emergence (Table 3) where Mkanakaufiti showed consistently late infestation. On the other hand, *Alectra* source × dormancy-breaking period interaction affected days to the first *Alectra* emergence where the Neno-Manyenye collection had an earlier emergence without dormancy period on the genotype used while after the dormancy-breaking period, Ntchisi-Chimanjamanja followed by Salima-Matumba and Lilongwe-Kamowa collection was seen in earlier emergence. However, the increasing dormancy-breaking period delayed the emergence of *A. vogelii*.

Interaction effects on *Alectra* shoot count at 9 WAP

Variety × *Alectra* source × dormancy-breaking period interaction significantly ($p>0.1$) affected *Alectra* shoot counts at 9 WAP (Table 4). On the other hand, cowpea variety × *Alectra* source × dormancy-breaking interaction revealed that Neno-Manyenye collections were more severely without dormancy breaking period on two varieties while Salima-Matumba (30-day sun drying) and Lilongwe-Kamowa (10 days sun drying) showed to be more dominant after a dormancy-breaking period on the collections across all dormancy-breaking period on *Alectra* shoot counts. Only Mkanakaufiti was revealed to be less infested by the collections used, as after dormancy-breaking Ntchisi-Chimanjamanja collections were seen as dominant. Eighty percent and above of the *A. vogelii* population was supported by IT82E-16 than Mkanakaufiti, either without or after the dormancy breaking period.

Interaction effects on *Alectra* shoot count at 10 WAP

Cowpea variety × *Alectra* source × dormancy-breaking period interaction significantly ($p>0.1$) affected *Alectra* shoot counts at 10 WAP (Table 5). Furthermore, Neno-Manyenye collections were observed with a high incidence without dormancy breaking on both varieties while after the dormancy-breaking period Salima-Matumba, followed by Lilongwe-Kamowa collections were observed with a high incidence on IT82E-16.

Table 1: *Alectra vogelii* collection sites, a global positioning system (GPS), elevation, and *Alectra* host crops.

Site	GPS	Masl	AE[+] zone	*Alectra* host crop
Neno- Manyenye	S 15º21.479'; E 034º53.788'	498	Low	groundnuts
Salima- Matumba	S 13º39.078'; E034º17.488'	576	Low	groundnuts
Lilongwe- Kamowa	S 14º11.584'; E 033º46.64'	1179	Mid	groundnuts
Dedza- Nyombe	S 14º16.710'; E 043º05.207'	1257	High	groundnuts
Ntchisi- Chimanjamanja	S 13º17.411'; E 033º53.237'	1277	High	groundnuts

AE[+] = Agro-Ecological, Masl = meter above sea level.

Table 2: Summary of F probabilities from the analysis of variance for days to first *Alectra* emergence (DFAE), *Alectra* shoot counts (AC) per pot at different weeks after planting (WAP), dead *Alectra* counts, and *Alectra* vigour score.

Source of variation	DF	F probability values								
		DFAE	AC 7 WAP*	AC 8 WAP*	AC 9 WAP*	AC 10 WAP*	AC 11 WAP*	AC 12 WAP*	Number of dead *Alectra* shoots*	*Alectra* vigour score
Block	3									
V	1	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
AS	4	0.972	0.573	0.414	0.066	0.040	0.138	0.5730	0.209	0.581
DB	3	0.294	0.701	0.790	0.433	0.699	0.735	0.7010	0.971	0.112
V x AS	4	0.764	0.158	0.164	0.062	0.094	0.170	0.1580	0.162	0.289
V x DB	3	0.030	0.529	0.962	0.210	0.352	0.616	0.5290	0.923	0.616
AS x DB	12	0.018	0.623	0.283	0.009	0.002	0.060	0.6230	0.929	0.376
V x AS x DB	12	0.166	0.532	0.257	0.010	0.006	0.072	0.5320	0.932	0.150
Grand mean		93.7	0.78	1.23	2.37	2.78	3.19	3.15	1.49	2.19
CV %	117	33.4	55.8	55.5	46.5	46.5	54.8	55.8	86.8	50

*Analysis was performed after square root transformation of the data $[(x +0.5)^{0.5}]$; Variety (V), *Alectra* source (AS), dormancy-breaking period (DB), Cowpea variety × *Alectra* source (V × AS); cowpea variety × dormancy-breaking period interaction, (V × DB) *Alectra* source × dormancy-breaking period interaction (AS × DB), and *Alectra* source × dormancy-breaking period × cowpea variety (V × AS × DB) interactions.

Table 3: Effects of variety × dormancy-breaking period and *Alectra* source × dormancy-breaking period interactions on days to first *Alectra* emergence.

Variety x dormancy breaking period interaction				
	Dormancy-breaking period (DB) (days)			
Variety (V)	0	10	20	30
IT82E-16	53.9	53.0	64.4	53.2
Mkanakaufiti	131.8	124.2	119.2	149.9
LSD 10 %		19.58		
F prob. (V x DB)		0.030		
Alectra source × dormancy-breaking period interaction				
	Dormancy-breaking period (DB) (days)			
Alectra source (AS)	0	10	20	30
Dedza-Nyombe	86.5	106.2	86.6	95.2
Ntchisi-Chimanjamanja	105.4	71.0	84.9	106.2
Lilongwe-Kamowa	82.5	72.7	120.0	93.4
Salima-Matumba	110.0	98.1	71.6	106.0
Neno-Manyenye	79.9	94.6	84.9	106.6
LSD 10 %		30.96		
F. prob. (AS x DB)		0.018		

Table 4: Effects of cowpea variety × *Alectra* source × dormancy-breaking period interactions on *Alectra* shoot counts at 9 WAP.

Variety × *Alectra* source x dormancy-breaking period interaction					
		Dormancy-breaking period (days)			
Variety (V)	*Alectra* source (AS)	0	10	20	30
IT82E-16	Dedza-Nyombe	3.16	2.93	3.65	3.01
	Ntchisi-Chimanjamanja	4.11	4.31	2.12	3.43
	Lilongwe-Kamowa	2.59	5.54	3.16	5.12
	Salima-Matumba	2.40	3.77	4.27	6.19
	Neno-Manyenye	5.13	4.07	5.48	3.91
Grand mean		3.48	4.12	3.74	4.33
Mkanakaufiti	Dedza-Nyombe	0.71	0.71	0.71	0.84
	Ntchisi-Chimanjamanja	0.71	1.34	1.25	0.71
	Lilongwe-Kamowa	0.97	0.71	0.71	0.84
	Salima-Matumba	0.71	0.71	0.84	0.71
	Neno-Manyenye	1.34	0.71	0.71	0.71
Grand mean		0.89	0.83	0.84	0.76
LSD 10 %			1.55		
F. prob (V x AS x DB)			0.010		

Table 5: Effects of cowpea variety × *Alectra* source x dormancy-breaking period interaction on *Alectra* shoot counts at 10 WAP.

Variety × *Alectra* source x dormancy-breaking period interaction					
Variety (V)	*Alectra* source (AS)	Dormancy-breaking period (DB) (days)			
		0	10	20	30
IT82E-16	Dedza-Nyombe	4	3.43	4.63	3.41
	Ntchisi-Chimanjamanja	4.76	5.18	2.94	4.02
	Lilongwe-Kamowa	2.98	4.46	5.03	7.21
	Salima-Matumba	2.94	6.47	3.97	6.16
	Neno-Manyenye	6.46	4.49	7.11	4.5
Grand mean		4.23	4.81	4.74	5.06
Mkanakaufiti	Dedza-Nyombe	0.71	0.71	0.71	0.84
	Ntchisi-Chimanjamanja	0.71	1.39	0.84	0.71
	Lilongwe-Kamowa	1.19	0.84	0.71	0.84
	Salima-Matumba	0.71	0.71	0.84	0.71
	Neno-Manyenye	1.43	0.84	0.71	0.71
Grand mean		0.95	0.90	0.76	0.76
LSD 10 %				1.81	
F. prob (V x AS x DB)				0.006	

However, Mkanakaufiti cowpea variety was observed with a high incidence of *Alectra* shoots after the dormancy-breaking period. After dormancy-breaking, *Alectra* shoot counts increased for 10 and 30 sun-dried collections and 81% of *Alectra* counts infested IT82E-16 than Mkanakaufiti. However, a drop in *Alectra* counts was observed from 0 up to 30 days of dormancy breaking on Mkanakaufiti.

Interaction effects on *Alectra* shoot count at 11 WAP

Variety × *Alectra* source × dormancy-breaking period interaction significantly (*p*<0.01) affected *Alectra* shoot counts at 11 WAP (Table 6). Neno collections were observed with the highest incidence without dormancy-breaking period on IT82E-16 while Neno-Manyenye, Salima-Matumba, and Lilongwe-Kamowa collections were more dominant after dormancy-breaking period on the *Alectra* shoot counts at 11 WAP. On the other hand, Lilongwe-Kamowa followed by Neno-Manyenye collections were more dominant on the Mkanakaufiti variety without a dormancy-breaking period but after dormancy breaking Ntchisi-Chimanjamanja collections consistently maintained high *Alectra* counts. Approximately, 80% of *Alectra* counts were observed on IT82E-16 as compared to Mkanakaufiti across all dormancy breaking period.

Effects of cowpea variety and *Alectra* source on days to first *Alectra* emergence and *Alectra* shoot counts per pot

Days to the first *Alectra* emergence were significantly affected by the cowpea variety but not the dormancy-breaking period and *Alectra* source (Table 7). Similarly, *Alectra* shoot count at all sampling times was significantly affected by varieties. However, few *Alectra* shoots appeared in the late phenological stage of Mkanakaufiti. Furthermore, *Alectra* shoot counts at 9 and 10 WAP were significantly affected by *Alectra* source while the dormancy breaking period did not significantly affect *Alectra* shoot counts at all sampling times. In addition, higher *Alectra* shoot counts at 11 and 12 WAP were observed on the dormancy-breaking period effect. Neno collections were observed with a very high incidence followed by Salima-Matumba and Lilongwe-Kamowa collections on *Alectra* shoot count from 7 to 12 WAP.

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Table 6. Effects of variety × *Alectra* source × dormancy-breaking period interaction on *Alectra* shoot counts at 11 WAP.

Cowpea variety × *Alectra* source × dormancy-breaking period interaction					
		Dormancy-breaking period (DB) (days)			
Variety (V)	*Alectra* source (AS)	0	10	20	30
IT82E-16	Dedza-Nyombe	5.01	5.06	5.17	4.36
	Ntchisi-Chimanjamanja	5.32	6.01	2.67	4.79
	Lilongwe-Kamowa	4.62	7.03	4.4	6.49
	Salima-Matumba	4.19	5.46	5.82	7.75
	Neno-Manyenye	7.66	5.49	7.8	4.8
Grand mean		5.36	5.81	5.17	5.64
Mkanakaufiti	Dedza-Nyombe	0.84	0.71	0.84	0.84
	Ntchisi-Chimanjamanja	0.71	1.56	1.00	0.71
	Lilongwe-Kamowa	2.59	0.97	0.71	0.84
	Salima-Matumba	0.71	0.71	0.84	0.71
	Neno-Manyenye	1.48	0.84	0.84	0.71
Grand mean		1.27	0.96	0.85	0.76
LSD 10 %		2.23			
F.prob (V x AS x DB)		0.072			

Table 7. Effects of cowpea variety and *Alectra* source on *Alectra* shoot counts (AC) per pot at different weeks after planting (WAP).

Factor	AC at 7 WAP*	AC at 8 WAP*	AC at 9 WAP *	AC at 10 WAP*	AC at 11 WAP*	AC at 12 WAP*
Variety						
IT82E-16	0.85[b]	1.75[b]	3.92[b]	4.71[b]	5.50[b]	5.39[b]
Mkanakaufiti	0.71[a]	0.76[a]	0.83[a]	0.84[a]	0.96[a]	0.98[a]
LSD 10 %	0.06	0.22	0.35	0.40	0.50	0.56
F. prob	<.001	<.001	<.001	<.001	<.001	<.001
Alectra source						
Dedza-Nyombe	0.74	1.14	1.96[a]	2.30[a]	2.85	2.99
Ntchisi-Chimanjamanja	0.81	1.22	2.24[ab]	2.57[a]	2.85	2.98
Lilongwe-Kamowa	0.77	1.26	2.45[ab]	2.89[ab]	3.45	3.00
Salima-Matumba	0.78	1.18	2.45[ab]	2.83[ab]	3.27	3.58
Neno-Manyenye	0.80	1.45	2.76[b]	3.28[b]	3.70	3.33
Grand mean	0.78	1.25	2.37	2.77	3.23	3.18
LSD 10 %	0.101	0.34	0.55	0.64	0.79	0.88
F. prob	0.63	0.414	0.066	0.04	0.14	0.21
CV %	26.20	55.50	46.50	46.50	49.30	55.80

*Analysis was performed after square root transformation of the data $[(x +0.5)^{0.5}]$

Dead *Alectra* counts at 14 WAP and *Alectra* vigour score

Dead *Alectra* counts at 14 WAP were significantly affected by the variety effect (Table 8) where IT82E-16 was observed with high death counts compared to Mkanakaufiti.

However, both Alectra source and dormancy-breaking period did not affect dead Alectra counts. Alternatively, *Alectra vigour* score was significantly affected by the variety effect, where IT82E-16 registered a high vigour score compared to Mkanakaufiti. However, *Alectra* vigour score was not significantly affected by *Alectra*

source and dormancy-breaking period effects (Table 8).

ANOVA summary of *Alectra* biomass, cowpea biomass, cowpea yield, and yield Components

Variety × *Alectra* source interaction resulted in a significant ($p<0.05$) effect on the number of pods, pod weight (g/pot), and grain weight (g/pot). In contrast, *Alectra* source × dormancy-breaking period and variety×*Alectra* source × dormancy-breaking period

interactions did not affect the number of pods (Table 9). Conversely, *Alectra* fresh and dry biomass, fresh and dry cowpea biomass, number of pods, and grain weight were affected by the variety effect. On the other hand, the number of pods, and grain weight (g) was significantly ($p<0.01$) affected by *Alectra* source. At all sampling times, cowpea biomass, yield, and yield components were not affected by the dormancy-breaking period.

Table 8. Effects of cowpea variety on dead *Alectra* counts at 14 WAP and *Alectra* vigour score.

Variety	Number of dead *Alectra* shoots at 14 WAP	*Alectra* vigour score
IT82E-16	2.25[b]	3.89[b]
Mkanakaufiti	0.73[a]	0.49[a]
Grand mean	1.49	2.19
LSD 5%	0.4	0.34
F prob	<.001	<.001
CV %	86.8	50

Table 9: Summary of F probabilities from the analysis of variance for *Alectra* biomass, cowpea biomass, cowpea yield, and yield components per pot.

Source of variation	D.F	F probability values						
		Alectra fresh mass	*Alectra* dry mass	Cowpea fresh mass	Cowpea dry mass	Number of pods	Pod weight *	Grain weight *
Block	3							
V	1	<.001	<.001	<.001	<.001	<.001	<.001	<.001
AS	4	0.668	0.438	0.379	0.432	0.009	0.208	0.057
DB	3	0.900	0.951	0.649	0.324	0.737	0.396	0.827
V × AS	4	0.646	0.552	0.226	0.835	0.003	0.019	0.023
V × DB	3	0.792	0.659	0.467	0.129	0.504	0.551	0.871
AS × DB	12	0.421	0.402	0.974	0.952	0.080	0.404	0.309
V × AS × DB	12	0.483	0.452	0.815	0.938	0.020	0.161	0.348
CV %	117	51.8	52.5	39.3	39.7	49.4	30.4	30.9

*Analysis was performed after square root transformation of data $[(x +0.5)^{0.5}]$; Variety (V), *Alectra* source (AS), dormancy-breaking period (DB), variety × *Alectra* source (V × AS); variety × dormancy-breaking period, (V × DB) *Alectra* source x dormancy-breaking period (AS × DB), and *Alectra* source × dormancy-breaking period x variety (V × AS × DB) interaction

Effects of cowpea variety on *Alectra* and cowpea biomass (g) parameters

Both *Alectra* and cowpea biomass production were affected by variety effects, where, IT82E-16 was observed with a higher *Alectra* biomass than Mkanakaufiti (Table 10). However, cowpea biomass production was higher on Mkanakaufiti than on IT82E-16.

Interaction effects on the number of pods per pot

V × AS × DB ($p<0.05$) interaction significantly affected

the number of pods per pot on both genotypes used in the study (Table 11).

However, Ntchisi-Chimanjamanja *Alectra* collections before the dormancy-breaking period affected the number of pods per pot on IT82E-16, as they were lower after the dormancy-breaking period. The same observation was made on Salima-Matumba *Alectra* collections (sun-dried for 20 days) followed by Lilongwe-Kamowa (sun-dried for 20 days) where pod

number per pot on IT82E-16 was affected. However, Neno-Manyenye *Alectra* collections affected the number of pods on Mkanakaufiti across all dormancy-

breaking periods plus before dormancy-breaking periods. In general, Mkanakaufiti was observed with higher pods as compared to IT82E-16.

Table 10. Effects of cowpea variety on *Alectra* and cowpea biomass (g/pot) parameters.

Variety	Fresh *Alectra* biomass * (g)	Dry *Alectra* biomass * (g)	Fresh cowpea biomass* (g)	Dry cowpea biomass * (g)
IT82E-16	2.35[b]	1.86[b]	3.15[a]	2.57[a]
Mkanakaufiti	1.62[a]	1.26[a]	6.70[b]	5.20[b]
Grand mean	1.98	1.560	4.930	3.89
LSD 5 %	0.32	0.26	0.61	0.48
F. prob	<.001	<.001	<.001	<.001
CV %	51.80	52.500	39.300	39.70

*Analysis was performed after square root transformation of data $[(x +0.5)^{0.5}]$.

Table 11: Effects of cowpea variety × *Alectra* source × dormancy-breaking period interaction on the number of pods per pot.

Variety × *Alectra* source × dormancy-breaking period interaction					
		Dormancy-breaking period (DB) (days)			
Variety (V)	*Alectra* source (AS)	0	10	20	30
IT82E-16	Dedza-Nyombe	3.50	5.25	4.00	3.75
	Ntchisi-Chimanjamanja	2.25	4.50	6.25	4.25
	Lilongwe-Kamowa	4.75	1.75	5.00	3.75
	Salima-Matumba	4.75	3.25	0.25	2.25
	Neno-Manyenye	3.00	4.25	4.25	4.00
Grand mean		3.65	3.80	3.95	3.60
Mkanakaufiti	Dedza-Nyombe	9.75	14.75	10.5	7.5
	Ntchisi-Chimanjamanja	18	10.25	10.25	12.75
	Lilongwe-Kamowa	13.5	13.75	13.75	21.25
	Salima-Matumba	14	12.25	15	11
	Neno-Manyenye	7	6.25	6.75	14
Grand mean		12.45	11.45	11.25	13.30
LSD 5 %		5.49			
F prob (V × AS × DB)		0.020			

Interaction effects on pod weight (g/pot)

Variety × *Alectra* source interaction affected pod weight (g/pot) where lower pod weight was observed on IT82E-16 genotype across the *Alectra* sources as compared to Mkanakaufiti (Table 12). On the other hand, a higher cowpea pod weight per pot interaction was observed on seeds sourced from Lilongwe-Kamaowa, infested on Mkanakaufiti genotype. Salima-Matumba and Neno-Manyenye *Alectra* collections consistently affected pod weight on IT82E-16 and Mkanakaufiti, respectively.

Interaction effects on grain weight (g/pot)

Variety × *Alectra* source interaction significantly affected grain weight (g/per pot) with a higher interaction of grain yield on Mkanakaufiti infested with collections sourced from Lilongwe-Kamowa (Table 13). Grain weight (g) on IT82E-16 × Salima-Matumba *Alectra* collections interaction was the lowest as an indicator of severity. There was no difference amongst *A. vogelii* sources on IT82E-16 while a significant suppression lowest weight for Mkanakaufiti was observed on Neno-Manyenye collections.

Effects of variety and *Alectra* source on yield and yield components

The number of pods and grain weight (g/pot) were significantly affected by variety and *Alectra* source effects, where high yield output was realized on Mkanakaufiti (Table 14). Yield and yield components were drastically affected by the high incidence of *Alectra* collections from Neno-Manyenye and Salima-Matumba districts, however, the traits were significantly higher on the genotypes when infested with Lilongwe-Kamowa, Ntchisi-Chimanjamanja, and Dedza-Nyombe *Alectra* collections. Nevertheless, yield and yield components of cowpea varieties were not affected by the Dormancy-breaking period on the *Alectra* collections used.

Table 12. Cowpea Variety × *Alectra* source interaction effects on pod weight (g/pot).

Variety (V)	*Alectra* source (AS)				
	Dedza-Nyombe	Ntchisi-Chimanjamanja	Lilongwe-Kamowa	Salima-Matumba	Neno- Manyenye
IT82E-16	2.34	2.43	2.35	1.78	2.20
Mkanakaufiti	3.87	4.17	3.56	4.32	4.74
LSD 5 %			0.68		
F prob (V × AS)			0.019		

Table 13. Effects of cowpea variety × *Alectra* source interaction on grain weight (g/pot).

Variety (V)	*Alectra* source (AS)				
	Dedza-Nyombe	Ntchisi-Chimanjamanja	Lilongwe-Kamowa	Salima-Matumba	Neno- Manyenye
IT82E-16	2.03	2.05	2	1.53	1.93
Mkanakaufiti	3.38	3.49	2.86	3.46	4.06
LSD 5 %			0.58		
F prob (V × AS)			0.023		

Table 14. Effects of cowpea variety and *Alectra* source on yield and yield components.

Factor	Number of pods per pot	Grain weight per pot* (g)
Variety		
IT82E-16	3.75[a]	1.91[a]
Mkanakaufiti	12.11[b]	3.45[b]
LSD 5 %	2.23	0.26
F. prob	<.001	<.001
Alectra source		
Dedza-Nyombe	7.38[ab]	2.71[ab]
Ntchisi-Chimanjamanja	8.56[bc]	2.77[ab]
Lilongwe-Kamowa	9.69[c]	3.00[b]
Salima-Matumba	7.84[abc]	2.50[a]
Neno- Manyenye	6.19[a]	2.43[a]
Grand mean	7.93	2.68
LSD 5%	1.940	0.41
F. prob	0.009	0.05
CV %	49.40	30.90

*Analysis was performed after square root transformation of data [$(x +0.5)^{0.5}$]

Effect of dormancy-breaking period and site on organic carbon (%) in *Alectra* collections

Organic carbon (%) was higher on *Alectra* collections without dormancy breaking while those sun-dried for 30 days had the lowest organic carbon % (Table 15). However, Neno-Manyenye collections were observed with the lowest organic carbon content as compared to all the sources. On the other hand, *Alectra* weight in 27 cm^3 vials and *Alectra* density was lower on Neno-Manyenye collections. N (%) was higher on collections sun-dried for 30 days while non-sun-dried collections were observed with lower quantity. Only Salima-Matumba collections were observed with lower nitrogen percentages.

Table 15. *Alectra vogelii* organic carbon (%), nitrogen (%), seed weight (g), and seed density (g/cm3).

Dormancy-breaking period (Days)	Organic carbon (%)	Nitrogen (%)	Weight in 27 cm^3 vial (g)	density (g/cm^3)
0	8.07 ± 3	0.05±0.01	2.56 ± 0.66	0.10 ± 0.02
10	7.54 ± 2.40	0.06±0.03	2.12 ± 0.33	0.08 ± 0.01
20	7.54 ± 1.92	0.06± 0.02	2.36 ± 0.83	0.09 ± 0.03
30	7.26 ± 2.08	0.07± 0.01	2.20 ± 0.87	0.08 ± 0.03
Alectra source				
Dedza-Nyombe	8.63 ± 0.97	0.07±0.02	2.07 ± 0.17	0.08 ± 0.01
Ntchisi-Chimanjamanja	6.83 ± 2.09	0.05±0.01	3.20 ± 0.66	0.12 ± 0.02
Lilongwe-Kamowa	9.13 ± 0.95	0.078±0.01	2.26 ± 0.93	0.08 ± 0.03
Salima-Matumba	8.56 ± 2.28	0.04±0.01	2.21 ± 0.25	0.08 ± 0.01
Neno- Manyenye	4.87 ± 1.73	0.07±0.02	1.83 ± 0.14	0.07 ± 0.01
Overall mean	7.09±0.02	0.06±0.02	2.31±0.67	0.09±0.02

Presented are means with their standard deviation and no ANOVA

DISCUSSION

Interaction effects

Results revealed that cowpea variety × dormancy-breaking period and *Alectra* source × dormancy-breaking period interactions affected days to the first *Alectra* emergence. This was due to the susceptibility of cowpea varieties used, the temperature difference in the sites of *Alectra* seed collection, *Alectra* seed biochemistry, root exudate levels released by cowpea varieties, and other unknown factors not mentioned. Furthermore, earlier emergence was observed on *Alectra* seeds dried for 10 days which revealed the effectiveness of dormancy breaking in the study but contradicted other studies where seeds are dried for 30 days (CABI, 2017; Phiri et al., 2019). However the study increased the dormancy-breaking period, delayed *Alectra* emergence on both Mkanakaufiti and IT82E-16. This could be due to the cool season when the trial was conducted although *Alectra* seeds germinate anytime when host plants are available. Alternatively, cowpea variety × dormancy-breaking period interaction significantly affected DFAE, where an increased dormancy period delayed the emergence of *A. vogelii.*

The seed dormancy breaks easily as it occurs at a dry room temperature (Joel et al., 2017). Significant interactions were observed on collections with dormancy breaking as compared to without. Results revealed that cowpea variety × dormancy-breaking period and *Alectra* source × dormancy-breaking period interactions affected days to the first *Alectra* emergence (DFAE). This was due to the susceptibility, however, delayed emergence of *A. vogelii* on the Mkanakaufiti variety reflected a resistance mechanism which probably resulted in lower yield reduction and early infestation may guarantee high yield reduction (Kutama et al., 2014; Dieni et al., 2018) though, some tolerant genotypes may overcome the pressure thereby, leading to reasonable yield.

CV × AS × DB, AS × DB, and CV × AS interactions significantly affected the number of *Alectra* shoots at 9 and 10 WAP, which revealed diverse reactions of the cowpea varieties on the collection used. Though AS × DB interaction was significant, Neno-Manyenye collections across all dormancy-breaking periods were more dominant while on CV × AS × DB interaction, only Neno-Manyenye collections across all dormancy-breaking

periods were observed with a high incidence followed by Salima-Matumba collections. Furthermore, Neno-Manyenye *Alectra* collections were observed with a higher incidence without dormancy while Salima-Matumba and Lilongwe-Kamaowa collections were more dominant after dormancy breaking, therefore, revealing consistency effects on the yield and yield components. The high severity could be due to the warmest weather conditions in *Alectra* collection sites (CABI, 2017; Musango et al., 2022). However, *A. vogelii* shoot counts on Mkanakaufiti as compared to IT82E-16 were lower across all dormancy-breaking periods which reflected the resistant mechanism. A closer significant (*p*<0.01) trend was observed on *Alectra* source × dormancy and cowpea variety × *Alectra* source × dormancy-breaking interactions on *Alectra* shoot counts at 11 WAP. More than 80% of *A. vogelii* counts were supported by IT82E-16 than Mkanakaufiti either without or after the dormancy-breaking period. However, without dormancy-breaking the *Alectra* counts were higher while after dormancy-breaking the counts were dropping.

CV × AS × DB interaction affected the number of pods per pot which agrees with interactions in Tables 7 and 8. The results revealed the effects of *Alectra* shoots as they significantly affected pod numbers on Neno collections followed by Salima-Matumba collections across all dormancy-breaking periods. Furthermore, 77% of the pods were harvested from Mkanakaufiti infested with *Alectra* seeds without dormancy-breaking. However, after dormancy breaking, a low pod number (74%) was observed on Mkanakaufiti infested with 20 days sun-dried *Alectra* collection. The results revealed a low reduction in the number of pods in Mkanakaufiti infested with *Alectra* seeds sourced from Lilongwe-Kamowa which was an indicator of diminishing resistance mechanisms in the genotype (Kabambe et al., 2014). *A. vogelii* is more dominant in the mid-altitude where most of the cowpea genotypes are adaptable. This could be an indicator that the variety will not be resistant for a longer period (Vernon Kabambe, personal communication, 2018) and this agrees with the findings of Mwaipopo (2014), Makaza et al. (2021) and Makanjuola et al. (2023). On the other hand, cowpea variety × *Alectra* source interaction gave a significant effect on both pod weight (g) and grain weight (g) per pot which agrees with the effects on the number of pods.

Roles of cowpea variety on *A. vogelii* effects

Days to first *Alectra* emergence was affected by the varietal effect which revealed host specificity and suitability. Earlier *Alectra* invasions on IT82E-16 but not on Mkanakaufiti reflected a resistance mechanism. Even though, Mkanakaufiti is resistant to *A. vogelii* (Kabambe et al., 2014), in the study infestations occurred in the late phenological stage which could be due to juvenile resistance. Significantly, late infestation coincided with no *Alectra* seed production which probably could reduce soil seed bank, thereby, controlling the parasitic weed in the field. Furthermore, the emergence of *A. vogelii* on Mkanakaufiti indicated that resistance to the variety might be diminishing or the biochemistry of the parasitic weed is changing which is in agreement with climate and environmental changes (Mviha et al., 2011; Kabambe et al., 2014). This is worthy of exploring as the variety is considered resistant to *A. vogelii* in Malawi.

Alectra shoot counts at all times of sampling was significantly affected by the cowpea variety due to host specificity, as IT82E-16 was susceptible to *A. vogelii* in comparison to the Mkanakaufiti variety. However, IT82E-16 was severely infested with *A. vogelii* while Mkanakaufiti supported few which agreed with the findings of Mbwaga et al. (2010). This suggested that the cowpea varieties had different levels of susceptibility. Njekete et al. (2017), Jia et al*.* (2019) and Mounde et al. (2020) reported that strigolactone or alectrol determined the level of infestations on suitable host plants which could be the case here. However, in the late phenological stages, the variation disappeared due to high death counts on *Alectra* shoots which occurred before flowering thereby leading to a reduction in *A. vogelii* soil seed bank. Death of *Alectra* shoots mirrored resistance mechanisms as photo-assimilates could be limited on highly infested genotypes (Rubiales and Fernández-Aparicio, 2012; Karanja et al*.,* 2013; Phiri et al., 2018).

The number of dead *Alectra* shoots was affected by the cowpea variety which could be due to inhibitions of *Alectra* shoots on the host genotypes (Reuben, 2018). This agreed with the mechanism of resistance as some genotypes allow growth and development of the parasitic weed and then inhibition (James Bokosi, personal communication, 2018; Fernández-Aparicio et al., 2020). Mechanism of resistance by the host plants on the parasitic weed had been observed through delayed *Alectra* infestations on Mkanakaufiti, *Alectra* shoots death could be due to the genetics of the host crops (Dieni et al., 2018; Makaza, 2019). Though, IT82E-16 supported high *Alectra* shoots, mortality of *Alectra*

shoots was high which probably reflected starvation for growth resources, nitrogen content in the soil, high temperatures, relative humidity, and apoptosis reaction. The apoptosis mechanism is common in resistant cowpea varieties which probably inhibit the development of *Alectra* shoots (Hu et al., 2020). *Alectra* vigour score was affected by the variety effect which was in agreement with a higher number of *Alectra* shoots observed on IT82E-16 than Mkanakaufiti. Therefore, it was not a surprise as IT82E-16 was highly susceptible to *A. vogelii* which probably explains the high *Alectra* vigour scores observed in the study.

Higher biomass of *A. vogelii* on IT82E-16 revealed susceptibility levels of the host plant. The results agreed with the findings of Makaza et al. (2021), where *Alectra* infestations were associated with new sinks for growth thereby, decreasing the shoot biomass. The number of pods and grain weight per pot were significantly affected by the cowpea variety, with a high yield output realized on Mkanakaufiti. Cardoso et al. (2011), Kabambe et al. (2014), and Gwatidzo et al. (2020) reported that higher yields were observed on resistant varieties which agreed with the current findings. This indicated that the *Alectra* reaction had an impact on the amount of yield on IT82E-16 as it was highly susceptible to the parasitic weed and it was not a surprise to observe as susceptible cowpea varieties suffer yield reduction up to 100 % in a field situation (Boukar et al., 2016; CABI, 2017; Chikoye et al., 2020).

Roles of *A. vogelii* source on *A. vogelii* severity

Alectra shoot counts at 9 and 10 WAP were significantly affected by *Alectra* source which revealed the severity levels of collections used in the study. During this stage, *Alectra* shoot counts were at the peak, and in the later stages, the death of *A. vogelii* disrupted the numbers while in the earlier stages, it was too low to be significant. The changes in *Alectra* counts could be related to high temperatures, high humidity, and starvation for growth resources as in some pots, they overpopulated. Furthermore, Neno-Manyenye *Alectra* collections were consistently observed with a high incidence at all the sampling times which agreed with the warmest weather conditions of the district. On the other hand, Lilongwe-Kamowa and Salima-Matumba collections were also observed with a high incidence of *Alectra* on the cowpea varieties after dormancy breaking. This reflected that in low to mid-altitude areas, *Alectra* collections were more aggressive as they associated with high assimilates demand from the host

plant thereby increasing shoot counts. The difference in *Alectra* collections reaction could be due to soil fertility status, crop husbandry practices, and collection genetics which mirror site source.

The results revealed that grain weight (g) was significantly affected by *Alectra* source which probably agreed with an earlier observation of *Alectra* shoot counts. Yield and yield components of cowpeas were consistently reduced by the Neno-Manyenye collection followed by the Salima-Matumba collections which were observed with a high severity than other collections. This indicated that the severity of *A. vogelii* used varies with the site in their reaction toward yield and yield components. The behavior revealed by the collections could be due to environmental, altitude, and genetic factors. In contrast, biomass production was not affected by *Alectra* source which agrees with DFAE and *Alectra* shoot counts. Alonge et al. (2001) and Qasem (2006) reported that moderate infestation of *A. vogelii* on a non-suitable host plant probably leads to less export of assimilate to the parasite which ensures adequate biomass accumulation and grain development. Site differences in organic carbon were an indication that levels of carbohydrates in seeds varied which differentiated the collections' physiology. The low organic carbon percentage of Neno-Manyenye *A. vogelii* seeds could be due to higher temperatures in the collection site where the temperature ranges from 22 to 32°C (Anonymous, 2018) and after the ripening effect. This implied that respiration in the seeds had been continuous for a longer period in association with higher temperatures at the site. On the other hand, there could be the production of reactive oxygen species which have a detrimental effect on the seed lots (Hayat and Bailly, 2008; Griffo et al., 2023). The changes in the seed colour, size, and breakage could be attributed to seed ageing or desiccation (Umarani et al., 2015; Plitta-Michalak et al., 2022). A high quantity of N (%) in *Alectra* seeds mirrors the maturity and vigour of the seeds (Taiz et al., 2015). However, longtime sun drying allowed the leaching of inhibitors in the seeds thereby allowing the conversion of nitrogen form into other forms (Banful et al., 2011; Taiz et al., 2015). Furthermore, the results indicated that as dormancy breaking was increasing N quantity increased too. This only was an indicator of dormancy release and probably some conversions occurred in the seed. The study has revealed that a dormancy breaking period is a need in enhancing seed chemical reaction and

might lead to deterioration if conditions are unfavourable.

Role of the dormancy-breaking period on *A. vogelii* severity

The result on *Alectra* shoot counts and days to the first *Alectra* emergence at all sampling times were not affected by the dormancy-breaking period though there was an increase in *Alectra* shoot counts. This contradicted the assumption that sun-dried collections could be more problematic than non-sun-dried ones which influence dormancy breaking as discussed earlier. Besides, this could be due to the genetics of the collections used, environmental conditions, and seed biochemistry (CABI, 2017). *Alectra* seeds being minute seeds fit Martin's description of dwarf rather than micro seeds because they have differentiated embryos (Phiri, 2018). As a result, little embryo growth is possible without rupturing the seed coat making morphological dormancy impossible in *Alectra* and *Striga* seeds. Therefore, dormancy breaking in the seed is easily achieved in a dry room temperature and warm stratification. However, it was assumed that collections sun-dried for 30 days could probably germinate earlier and more severely on both susceptible and resistant genotypes. This entails that *Alectra* seed dormancy breaking could occur easily on *Alectra* seeds once mature, dry and favourable conditions are available. Duke and Egley (2018) reported that *Alectra* seed coats lacked a palisade layer of the macroscelerids making them easily permeable to water. This revealed that the seed biochemistry of *Alectra* easily changes with a short duration of drying and conditioning, as sometimes in *Orobanchaceae* pre-conditioning is not a prerequisite for germination (CABI, 2017).

The dormancy-breaking period did not affect yield and yield components which were contrary to the expectation as collection sun-dried for 30 days was assumed problematic on the cowpea genotypes used. This was in agreement with the findings on days to the first *Alectra* emergence and the number *Alectra* shoot counts in the study. On the other hand, biomass production was not affected by the dormancy breaking period which agrees with NDFAE and *Alectra* shoot counts. Seeds are a source of organic carbon and mineral (N and P) nutrients for the growth of seedlings (Lamont and Groom, 2013). The drastic drop of organic carbon (%) in *Alectra* seeds sun-dried for 30 days could be due to chemical reactions in the seeds and the conversion of

seed products into other forms (Banful et al., 2011; Taiz et al., 2015). Dormancy breaking goes in with hand drop in OC contents; while without dormancy breaking, the contents remained higher. This implied that low amounts of minerals and organic carbon associated with low germination % as chemical reaction are low in the seed (Lamont and Groom, 2013; Těšitel, 2016). This could be attributed to the maturity of the seeds as drying is associated with the leaching of chemicals (Leubner-metzger, 2003; Daws et al., 2008; Singh, 2020). Some of the chemical reaction which occurs during maturity, after-ripening, and deterioration include lipid peroxidation, membrane disruption, DNA damage, and impairment of RNA and protein synthesis (Duke and Egley, 2018; Chhabra and Singh, 2019), which was not a surprise in the drop of OC.

The trends of OC (%) were similar to *Alectra* mass in 27 cm^3 vials (g) which agreed with the density of the *Alectra* collections (g/cm^3). The difference in masses could be due to the drop in OC (%) on Neno collections which is worth exploring. During seed maturation, OC (%) was transferred from the vegetation to the capsules of *Alectra* seeds which probably differentiate the ability of the collections (Salon et al., 2001; Phiri et al., 2018). Both the dormancy-breaking period and *Alectra* source showed variations in N contents in the seeds which was in agreement with the reaction of *Alectra* collections on the crop. After dormancy-breaking, N% increased while without the dormancy-breaking period, the content was lowest which agreed with the discussion on shoot counts effects.

CONCLUSION

This study has revealed that some implications of dormancy-breaking existed depending on the *Alectra* source. However, *Alectra* source appeared to influence *Alectra* shoot counts, grain weight, and shelling % for both cowpea varieties Mkanakaufiti and IT82E-16. On the other hand, the results have revealed that the Neno-Manyenye collections had a higher incidence without dormancy-breaking while Lilongwe-Kamowa and Salima-Matumba collections had a higher incidence after dormancy-breaking period due to variability in weather patterns at sites of the source. Even though Mkanakaufiti is resistant to the parasitic weed, the study has shown late infestation on the crop from the *Alectra* collection used which revealed apparent strain variability on the *A. vogelii* collection used, however, the study has confirmed

the resistance mechanism of Mkanakaufiti on A. vogelii. Nevertheless, the variety of reactions on the parasitic weed depends on the suitability of the host and compatibility of the parasitic weed with the host, though some resistant genotypes tend to lose the mechanism with time. On the other hand, the organic carbon content in *Alectra* seeds varied from the three agroecological zones which signified the collections variability due to warmer temperatures, relative humidity, and crop husbandry practices. Therefore, screening for resistance in crops to suppress the weed should be conducted.

A further study on the changes of *Alectra vogelli* seed on physiology and biochemistry sourced from different sites is vital. It is advisable to promote the use of resistant cowpea varieties like Mkanakaufiti to reduce the risk of severe infestations and enhance crop resilience against parasitic weeds. Furthemore, a comprehensive and integrated approach that combines host resistance, and climate-adapted management practices is recommended to effectively control and manage *Alectra* infestations in cowpea crops. Lastly, breeding and introduction of new cowpea genotypes with shorter duration, and large-seeded seeds to meet consumer preferences are also required.

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AUTHORS' CONTRIBUTIONS

Under VHK and JB's supervision, CKP conceived the idea, conducted experiments, analyzed data, and authored the manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

Data Availability Statement

Data are available upon request from the 1st author

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