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Cropping patterns influence on striga seed-bank

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A B S T R A C T

In this paper simultaneous use of trap crop, organic and inorganic soil amendments are discussed. This study shows that the most effective legume trap crops such as soybean and medium maturing cowpea produced results similar to those obtained with the ethylene treatment which indicates that the expensive ethylene treatment should not be promoted in the West African context. Results also showed that urea amendment reduced *Striga* seed-bank of soil and improved sorghum yield whereas poultry manure amendment gave stimulatory effect on *Striga* seed germination.

1. Introduction

Population pressure has resulted in the increase of land use, and more intensive agriculture. *Striga* has become not only a biological constraint to food production in sub-saharan Africa but also a socio - economic problem for resource poor farmers. These are forced to abandon their farms under high infestation conditions (Salle´, 1991). Yield losses averaged 24% (10 – 31%) but in areas of heavy infestation, losses reached 90 –100% in some years (Hess et al., 1996). Most effective control technologies involved high input agriculture such as the use of ethylene in the USA which achieved 92% depletion of viable *S. asiatica* seed with a single application of ethylene at 1.6kg/ha (Bebawi et al., 1985). However such high input control systems may not be an appropriate control technology for the majority of the resource poor farmers suffering from *Striga* infestation in sub-saharan Africa. Hence there is a need to look for simpler techniques as components of an integrated *Striga* control package which is adaptable to the African situation (Berner et al., 1996) Crops that are non-hosts to *Striga* but produce germination stimulants for *Striga* seeds which die in the absence of a host, have been termed trapcrops (Parkinson et al., 1987). The use of legume as a trap crop for *Striga hermonthica* control has been suggested by several authors (Sherif and Parker, 1986; Doggett, 1988) Legume rotation operates through two major mechanisms (1) suicidal germination of *Striga hermonthica* seeds in the soil and (2) soil fertility improvement.

Rotation cropping with a selected legume for one year has been shown to be effective in *Striga hermonthica* control (Berner et al., 1996). Eplee and Norris (1990) also reported 90% reduction in *S.asiatica* using cotton in a single season. However reports by Ramaiah (1981) show that at least three years of rotation are likely to be needed for benefits in *Striga* control. The practical limitation of the technique that few farmers will be prepared to give up growing their preferred cereal for a three year period, especially as the choice of alternative crops in most infested areas will be extremely limited. Double cropping a year with a selected early cultivar of cowpea may cause more suicidal germination of *Striga hermonthica* and improve yield of subsequent cereal than a single full season of cowpea cropping.

A system that would improve soil fertility to increase yield as well as reduce *Striga* infestation will be of double advantage. Good soil management practices involving the use of crop residues and organic manure have been reported effective control measure against *Striga* (Hosmani, 1978; Chidley and Drennan, 1987). Vogt et al., (1991) observed that *Striga* infestation decreased with increasing organic matter of the soil and that organic matter content seemed to be the most important factor which preserved the soil fertility. Since soil microbial biomass flourishes better in a medium rich in organic matter, organic or inorganic soil amendments may increase soil suppressiveness to *Striga hermonthica* and also improve soil conditions to increase yield of subsequent cereal.

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With the yield of cereals drastically reduced by *Striga* infestation leading to abandonment of farmland, a control option aimed not only at reducing *Striga* seed-bank in the soil but improving soil conditions to significantly increase yield of the subsequent cereal will be of great interest to the farmer. It was the objective of this study to evaluate the effect of different legume cropping patterns, ethylene and nitrogen sources on *Striga* incidence and sorghum yield.

2. Materials and methods

In 1999 – 2000, this study was carried out in two locations, Abuja farm (9° 15'N; 7° 20'E, 300m altitude, 1500mm annual rainfall) and Mokwa farm (9° 18'N; 5° 4'E , 457m altitude, 1100mm annual rainfall) both in the southern Guinea savanna zone of Nigeria. The two locations were chosen because of their severe infestation with *Striga hermonthica* and the fact that earlier research had shown that *Striga* strains differed between the two locations (Ikie et al., 2001). The predominant soil types are sandy loam ultisols (Mokwa) and sandy loam alfisols (Abuja) of moderate to low fertility. The crops of interest to farmers in both locations are maize(*Zea mays*), sorghum (*Sorghum bicolor* L. Moench) cowpea (*Vigna unguiculata* L.Walp.) and groundnut (*Arachis hypogea* L.).

2.1 Experimental design

In 1999, prior to the establishment of trials, the experimental sites at Abuja and Mokwa farm were artificially infested with *Striga hermonthica* seeds at the rate of 26,667 germinable seeds per m-2 (germination rate was 45%). The seeds had been collected from the previous year from farmers' fields in the vicinity of the corresponding experimental sites. This had been collected the previous year from farmers' fields in the vicinity of the corresponding experimental sites.

A randomized complete block design (RCBD) was used in 1999 with 4 replications in each location. The eight treatments tested are described in Table 1 and included medium maturing cowpea selected as a high *Striga* seed germination stimulant producer and nonselective to both locations (ALHSS) (Abuja and Mokwa) (Ikie et al., 2001) along with another medium maturing Rotation cropping cowpea with high *Striga* stimulating ability to Abuja location *Striga* but relatively low stimulating ability to Mokwa location *Striga* (LSHSS), medium maturing soybean (cultivated widely by farmers in the ecological zone), weedfree fallow, weedfree fallow followed by ethylene 1.6kg/ha injection, and continuous sorghum in different cropping patterns.

In 1999 plot size was 90m2(18 x 5m). The land was prepared using a tractor drawn harrow. The legume was seeded at two seeds per hill and spaced 40cm between rows and 20cm within rows and thinned to one stand per hill. The sorghum was planted at six seeds per hill and spaced 75cm between rows and 25cm within rows and thinned to one stand per hill in 1999. Gramoxone at the rate of 4lha-1was applied a day after sorghum planting and hoe weeding was carried out twice before harvesting on all plots except sorghum plots weeding was by hand weeding leaving *Striga* plants. Karate 2.5 EC (lambda-cyhalothrin 25g a.i/l) at the rate of 4l ha^{-1} was applied to control insect pests.

In 2000, the main plots of $90m^{-2}$ were split into three subplots of $30m^{-2}$ each so as to test the effect of three sub-treatments i.e. organic nitrogen (poultry manure applied at rate equivalent to 100kg N/ha, inorganic nitrogen (urea applied at a rate 100kg N/ha, and a control (0 kg N ha^{-1}) . Both the manure and the urea were incorporated into the soil during land preparation. All plots were [planted to sorghum (Mokwa local cultivar) as indicator crop. The sorghum was planted at six seeds per hill and spaced 75cm between rows and 25cm within rows and thinned to one stand per hill.

2.2 Agronomic practices

In 1999, land was prepared by harrowing once, after which weighed *Striga hermonthica* seeds mixed with sieved sand was applied uniformly to the entire experimental siteand then harrowed twice again to mix the *Striga* seeds with the soil prior to treatment establishment.

Phosphorus (P) was applied in the form of triple super-phosphate to all plots at the rate of 15kg P ha^{-1} to eliminate this element as a limiting factor to plant (legume) growth. Only the Sorghum plots received Nitrogen (N) fertilizer in the form of urea at a rate of 30kg N ha^{-1}.

In 2000, land was prepared using hoes avoiding movement of soil from one plot to the other. Each plot received Phosphorus (P) at a rate of 15kg P ha^{-1}, potassium (K) at a rate of 34kg K ha^{-1} during land preparation. Phosphorus was applied as triple superphosphate and Potassium as muriate of potash.

Weed was controlled using gramoxone at a rate of 4l ha^{-1} a day after planting and hand weeding was carried out weekly on all plots leaving only *Striga* plants.

2.3 Sampling and analytical procedures

Prior to establishment of trial in 1999, 15 core soil samples were taken from each main plot at 0 – 15 cm depth, bulked and sub sampled to produce one composite sample per plot. The procedure was repeated prior to the onset of 2000 soil amendment/ sorghum cultivation from main plots also.

Soil properties (pH, OM, N, P, K) and the nutrient content (N,P,K) of the applied manure were measured following routine procedures (IITA, 1981). *Striga* densities in the soil were determined using the potassium carbonate separation method and were calculated for a soil depth of 150mm with an assumed bulk density of 1.5 gcm^{-3} (Berner et al., 1997). Crop yields and *Striga* plant densities were determined in each plot from five middle rows leaving the border hills. *Striga* plant densities was measured weekly from 3 weeks after planting (WAP) but maximum emerged *Striga* per sorghum plant was irrespective of the period of observation (time of maximum emerged *Striga* was not uniform across treatments). Grains and stover dry matter yields were determined after drying representative samples of 500g to constant weight at 650C. Grains yields were adjusted to 12% moisture content. Visual *Striga* damage rating was done using a scale of 1 – 9, with 1 being a normal healthy growing sorghum plant, and 9 being dead or nearly dead plant (Kim, 1991).

Table 1
Treatments applied in 1999.

Treatment number	Crop species/variety	Maturity Class of legume	Seeding rate (Plant stands/ha)
1	Soybean (TGX 1448-2E) Early season cropping	Medium	125000
2	Cowpea (LSHSS) (81D-1137) Early season cropping	Medium	125000
3	Cowpea (ALHSS) (IT90K-277-2) Double cropping	Medium	125000
4	Cowpea (ALHSS) (IT90K-277-2) Early season cropping	Medium	125000
5	Cowpea (ALHSS) (IT90K-277-2) Late season cropping	Medium	125000
6	Susceptible sorghum (Mokwa local)		53333
7	Fallow (weedfree)		
8	Fallow (weedfree) followed with ethylene injection		

Data were analyzed with SAS (SAS, 1989) applying the mixed model procedures. The data on *Striga* plant densities were transformed using square root transformation $(X + 0.5)^{1/2}$. Results are presented as treatment means and mixed model contrast probabilities and are based on least square means.

3. Results and discussions

At the onset of the trial, the total soil N, organic carbon (C), C/N ratio, and available phosphorus (P) contents indicates the soils were degraded and had poor nutrient status (Table 2).

Table 2
Chemical properties of soil (0 – 150mm) from the experiment fields prior to the establishment of the trials.

Location	pH (in water)	Org C%	N%	C/N ratio	P (mg kg $^{-1}$)
Mokwa	5.6	0.26	0.03	8.8	11.85
Abuja	5.5	0.49	0.05	9.2	23.75

3.1 Striga emergence and sorghum yield in 1999.

Maximum emerged *Striga hermonthica* per sorghum stand in Mokwa and Abuja were $2.89^{+\ 0.31}$ and $3.75^{+0.02}$ respectively; Sorghum grain yields were $0.51^{+\ 7 \times 10^{-4}}$ and $0.57^{+\ 0.02}$ t/ha respectively.

3.2 Striga emergence in 2000.

In Mokwa location all cropping patterns had significantly ($P < 0.01$) lower maximum emerged *Striga* than continuous sorghum plots (3.86 Striga plants per sorghum stand) (Table 3). In contrast in Abuja all cropping patterns had significantly ($P < 0.01$) higher maximum emerged *Striga* than continuous sorghum plots. This at first sight counterintuitive result is due to the fact that the Striga infestation and pressure was so strong at the Abuja site that the sorghum crop was so severely infested damaged that it could not support striga emergence.

3.3 Striga emergence in 2000.

In Mokwa location all cropping patterns had significantly ($P < 0.01$) lower maximum emerged *Striga* than continuous sorghum plots (3.86 Striga plants per sorghum stand) (Table 3). In contrast in Abuja all cropping patterns had significantly ($P < 0.01$) higher maximum emerged *Striga* than continuous sorghum plots.

At Mokwa, the Striga incidence after the soybean trap crop (1.46 Striga plants per stand) was significantly ($P < 0.02$) less than after the cowpea traps and similar to the number of emerged Striga after fallow + ethylene treatment (1.88 Striga plants per sorghum stand). However, no differences were observed between the previous cowpea treatments (trt 2, 3, 4, 5).

With regards to soil amendments, in both locations, the control treatment (sorghum) had significantly ($P < 0.01$) lower maximum emerged *Striga* than the poultry manure amended plots but was not significantly different from the urea amended plots, however the poultry manure amended plots had significantly (P < 0.01) higher maximum emerged *Striga* than the urea amended plots (Table 4).

3.4 Striga symptom rating

In both locations, sorghum in plots preceded by sorghum had significantly (P < 0.01) higher *Striga* rating than all other cropping patterns (Table 3). In Abuja and Mokwa, the control plots had significantly higher (P< 0.01) *Striga* rating than poultry manure amended and urea amended treatments. Poultry manure and urea amended treatments were not different (P < 0.07) from each other in Abuja whereas poultry manure amended treatment had significantly (P < 0.02) higher *Striga* rating than urea amended treatment in Mokwa (Table 4).

Table 3

Treatment effects on maximum emerged Striga plants and Striga symptom rating, and selected contrast probabilities.

		Maximum emerged Striga per sorghum stand		Striga symptom rating	
Treatment	Number	Mokwa	Abuja	Mokwa	Abuja
Soybean	1	1.46	4.55	4.58	4.91
Cowpea (LSHSS)	2	2.03	4.99	3.25	4.75
Cowpea (ALHSS) (double cropping)	3	2.38	4.95	4.25	4.41
Cowpea (ALHSS) (early cropping)	4	2.20	4.39	3.5	4.08
Cowpea (ALHSS) (late cropping)	5	2.35	4.43	4.5	4.91
Fallow	7	2.15	4.24	3.41	5.91
Fallow + ethylene	8	1.88	4.34	3.58	4.50
Sorghum	6	3.86	0.70	7.91	9.00

Table 4

Soil amendment effects on maximum emerged Striga plants and Striga symptom rating.

	Maximum emerged Striga per sorghum		Striga symptom rating	
Treatment	Mokwa	Abuja	Mokwa	Abuja
Control	2.01	3.91	5.15	5.96
Poultry manure	2.74	4.63	4.25	5.22
Urea	2.11	3.68	3.71	4.75

Table 5

Treatment effects on sorghum stover and grain weight, and selected contrast probabilities.

		Stover yield (t ha^{-1})		Grain (t ha^{-1})	
Treatment	Number	Mokwa	Abuja	Mokwa	Abuja
Soybean	1	9.41	2.52	0.69	0.39
Cowpea (LSHSS)	2	11.12	3.19	1.15	0.51
Cowpea (ALHSS) (double cropping)	3	9.59	3.52	0.71	0.54
Cowpea (ALHSS) (early cropping)	4	10.86	4.22	0.99	0.83
Cowpea (ALHSS) (late cropping)	5	8.75	3.55	0.66	0.65
Fallow	7	9.64	2.63	1.03	0.44
Fallow + ethylene	8	10.40	4.30	1.03	0.74
Sorghum	6	1.46	0.00	0.05	0.00

3.5 Effect of cropping patterns on sorghum yields in 2000

a) Grain yield

At both sites, all tested treatments produced higher grain yield than the control treatment (continuous sorghum, trt 6) (Table 5). In Mokwa, sorghum preceded by medium maturing cowpea (trt 2) had significantly (P < 0.04) higher grain yield than sorghum preceded by soybean (trt 1) and then sorghum preceded by double cropped (trt 3) and late cropped cowpea (trt 5), (Table 5). In Abuja similar to the trend observed in Mokwa, sorghum after soybean performed poorly and was significantly out-yielded by sorghum preceded early and late cropped cowpea (trt 4 and 5) and by previous fallow + ethylene treatment (trt 8). Interestingly, at Abuja tha fallow + ethylene treatment (trt 8) as compared to the previous fallow treatment (trt 7) increased sorghum yield in 2000 by more than 60 to 0.74t ha^{-1} (P < 0.06). Sorghum preceded by double cropped cowpea (trt 2) and sorghum preceded by fallow and ethylene injection (trt 8) had significantly (P < 0.02) higher grain yield than sorghum preceded by medium maturing soybean (trt 1).

Sorghum preceded by all medium maturing cowpea(ALHSS) treatment group had significantly (P < 0.02, 0.05) higher grain yield than medium maturing soybean in Abuja (P <0.02) and Mokwa (P < 0.05).

b) Stover yield

In both locations, all cropping patterns had significantly higher stover weight than sorghum in plots preceded by continuous sorghum (trt 6) (Table 5).

In Abuja stover yields varied widely from 0 t ha^{-1} (continuous sorghum. trt 6) to 4.30 t ha^{-1} produced by sorghum after fallow + ethylene (trt 8). Sorghum preceded by soybean (trt 1) had significantly (P < 0.02) lower stover weight than sorghum preceded by early cropped cowpea(trt 4), and sorghum preceded by fallow and ethylene (trt 8) (Table 5). Also sorghum preceded early cropped cowpea (trt 4), and those preceded by fallow and ethylene injection had significantly (P< 0.03, 0.02) higher stover weight than sorghum preceded by fallow respectively. Sorghum preceding all medium maturing cowpea treatment group had significantly (P < 0.04) than sorghum preceded by medium maturing soybean.

In Mokwa all cropping patterns had significantly (P < 0. 01) higher stover weight than sorghum in plots preceeded by sorghum but the former were not different from each other (Table 5).

3.6 Effect of soil amendments on sorghum yields in 2000

a) Grain yield

The effect of soil amendment treatments is shown in Table 6. At both sites, the urea treatment produced the highest yields of 1.04 t ha^{-1} at Mokwa and 0.64 t ha^{-1} at Abuja.

At Mokwa sorghum in poultry manure amended plots had significantly (P < 0.01) higher grain yield than sorghum that had not received any amendments whereas no such differences occurred at Abuja.

b) Stover yield

The urea treatment produced the highest stover yields at both locations. At Mokwa, the poultry manure treatment (9.16 t ha-1) clearly outyielded (P<0.01) the control treatment whereas no such difference was observed at Abuja (Table 6).

3.7 Striga seed density

In 1999, substantial treatment effects were observed on the *Striga* seed-bank (Table 7).

All cropping patterns significantly (P < 0.01) reduced *Striga* seed-bank compared to sorghum plots. All cropping patterns besides sorghum plots were not different from each other except fallow(T7) plots that had significantly higher *Striga* seed-bank/m2 than (T1,T2,T8) (Table 7). Legume rotation treatments, fallow with ethylene injection, and fallow, resulted in *Striga* seed density ranging from (26,437 – 38,892 seeds/m^2) while sorghum plots resulted in 56, 671seeds/m^2 as translated from Table 7 .

4. Discussion

The higher *Striga* emergence in sorghum preceded by sorghum (Continuous sorghum) in Mokwa location over the other cropping patterns and the significant differences in *Striga* seed density, *Striga* rating, and stover weight between all cropping patterns and continuous sorghum cropping could be as a result of the additional increase in *Striga* seed-bank following previous (1999) sorghum cropping. Parker (Parker, 1991) asserted that continuous cropping is generally considered a significant factor in build-up of infestation. Increasing number of *Striga hermonthica* is not surprising as traditional sorghum cropping has been linked to increased *Striga hermonthica* seed-bank and emerged *S. hermonthica* on maize crops in the northern savanna of Nigeria (Weber, 1995). The lower *Striga* emergence of the legume cropping patterns may be due to their *Striga* seed-bank reduction ability. Doggett (1984) suggested that traditional African cropping systems which included prolonged fallow, rotations, and intercropping, kept *S.hermonthica* at moderate levels. The significantly higher grain yield of all cropping patterns over continuous sorghum may be connected with the *Striga* reduction ability of all the cropping patterns compared to the continuous sorghum cropping. The significantly higher grain yield observed across all cropping patterns (except continuous sorghum) over soybean rotation may be connected with the low *Striga* seed stimulating ability of the late maturing soybean to Mokwa *Striga* population. Berner et al., (1995) pointed out that although the cut root technique assay is subject to chemical artifacts from root destruction, the efficacy rankings of cultivars evaluated by the assay correlate significantly with *S. hermonthica* parasitism of sorghum and sorghum yield in the field under a 1-year rotation. The difference not observed in *Striga* rating and stover weight with fallow followed by ethylene injection and fallow followed by sorghum compared to all other cropping patterns may be connected with *Striga* reduction ability of ethylene through suicidal germination of *Striga hermonthica* seeds and natural decline in *Striga* seed-bank. Odhiambo and Ransom (1994) observed a rather large decline in *Striga* numbers between seasons. The significantly higher *Striga* emergence observed with sorghum preceded by ethylene injection in Mokwa over sorghum preceded by the cowpea (ALHSS) yet higher yield of the former over the latter may not be confusing. Kim (1994) observed with maize that *Striga* emergence count is highly environment dependent and caution must be taken in its interpretation. This may have also accounted for why there was no significant difference between the two cropping patterns in *Striga* emergence and subsequent sorghum grain yield in Abuja.

The significantly higher *Striga* emergence observed with poultry manure across the periods of observation over urea amendment and the control may be connected with enhancement of activity of ethylene producing bacteria which possibly stimulated the *Striga* seed to germinate in the presence of a susceptible host (sorghum) coupled with the high stimulant production of the host crop. Goodlass and Smith (1978a,b) observed a close correlation between microbial ethylene production and organic matter content in soils. Kranz (1997) reported ethylene emission of soils from compound fields much higher than bush fields with regards to soils of Northern Ghana. Saunders (1993) had found that manured sorghum plots had 40% more *Striga* plants above ground than unmanured plots. Sherif and Parker (1986) found stimulatory effect in poultry manure on *Striga* emergence.

Table 6
Soil amendment effects on sorghum stover and grain yields.

	Stover yield (t ha $^{-1}$)		Grain (t ha $^{-1}$)	
Treatment	Mokwa	Abuja	Mokwa	Abuja
Control	7.05	2.46	0.52	0.36
Poultry manure	9.16	2.74	0.81	0.38
Urea	10.51	3.77	1.04	0.64

Table 7
Elutriation of soils collected after 1999 cropping.

Treatment	Number	Number of Striga seeds/200g soil
Soybean	1	23.50
Cowpea (LSHSS)	2	23.55
Cowpea (ALHSS) (double cropping)	3	29.12
Cowpea (ALHSS) (early cropping)	4	31.00
Cowpea (ALHSS) (late cropping)	5	25.75
Fallow	6	50.37
Fallow + ethylene	7	34.57
Sorghum	8	4.76

Urea amendment not significantly different from the control in *Striga* emergence may be deceitful because the highly stunted sorghum stands with a very low stover weight would not have been able to sustain itself to bring up to emergence all the possibly stimulated *Striga* seeds. Kim (1991, 1994) observed with maize that *Striga* emergence count is highly environment dependent and caution must be taken in its interpretation and that highly susceptible plants when infected early do not show any emerged *Striga* plants because the host could not support parasite emergence.

In Abuja the significantly higher *Striga* emergence in all cropping patterns over continuous sorghum may be connected with the higher *Striga* parasitism following previous (1999) sorghum cropping which the host crop (sorghum) could not support which then led to complete crop failure in 2000. Hess et al., (1996) reported that there could be yield loss 90-100% under heavy infestation.

The significantly higher grain yield of sorghum preceded by ethylene and those preceded by the cowpea (ALHSS) over sorghum preceded by fallow and sorghum preceded soybean may be due to severity of infestation sequel to stimulating ability of the soybean in Abuja location (25 %) as against that of the cowpea ALHSS (41%). The significantly higher *Striga* rating of sorghum in plots preceded by the soybean over the cowpea (LSHSS) and those preceded by ethylene may be due to the *Striga* seed stimulating ability of the cowpea (LSHSS)(34%) as against (25%) of the soybean and suicidal seed germination by ethylene.

The significantly higher grain yield of urea over poultry manure amendment may be due to the ability of urea to inhibit *Striga* seed germination and thus reduced *Striga* seed-bank. Hess and Ejeta (1987) found inhibitory effect of 100kgN/ha on *Striga* thus ameliorating *Striga* parasitism. This might have also accounted for the significantly higher stover weight and lower *Striga* rating of urea amendment over those of poultry amendment and the control.

5. Conclusion

Rotation with a legume selected for its ability to stimulate *Striga* seed germination is an effective *Striga* control mechanism. The most effective legume trap crops such as soybean and medium maturing cowpea produced results similar to those obtained with the ethylene treatment which indicates that the expensive ethylene treatment should not be promoted in the West African context. Soybean proved to be a more effective trap-crop than the tested cowpea varieties. Different cowpea varieties and cropping patterns did not seem to affect *Striga* incidence. Soil amendment with urea reduced the *Striga* seed-bank and improved sorghum yield, whereas poultry manure amendment stimulated *Striga* seed germination. This study therefore suggests that the application of organic manure may not lead to reduced *Striga* incidence in the short term.

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