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Host-parasite dynamics of *Sorghum bicolor* and *Striga hermonthica* – The influence of soil organic matter amendments of different C:N ratio

G.C. Ayongwa[a,b,1], T.J. Stomph[a,*], T.W. Kuyper[c]

[a] Centre for Crop Systems Analysis, Wageningen University, P.O. Box 430, 6700 AK Wageningen, The Netherlands
[b] Institute of Agricultural Research for Development (IRAD), P.O. Box 415, Garoua, Cameroon
[c] Department of Soil Quality, Wageningen University, P.O. Box 47, 6700 AA Wageningen, The Netherlands

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ABSTRACT

The effect of organic amendments on the interactions between *Striga hermonthica* and a sorghum host was studied in a field experiment during three cropping seasons, following a three-factorial design with (i) bare fallow versus continuous cropping, (ii) two *Striga hermonthica* infection levels and (iii) five organic matter levels, a single inorganic fertiliser treatment of 120 kg N ha^{-1} and a control. The effects of two different cotton by-products and their mixtures on sorghum yield were well described by their N-mineralisation pattern. The impact of organic amendments in the sorghum production system was directly related to N-mineralisation in the three cropping seasons. There was an increasing negative effect of organic matter on *S. hermonthica* as the quality of the applied material increased. The emerged numbers of *S. hermonthica* were well described by N-release after one month, while *S. hermonthica* biomass and sorghum biomass were well described by N-release after three months. As a stand-alone measure, addition of low-quality organic matter is disadvantageous in cropping systems with high *S. hermonthica* seed densities, as it does not improve sorghum performance compared to no addition of organic matter, while *S. hermonthica* numbers increase. Implications for integrated soil fertility and *S. hermonthica* management under different infection levels of *S. hermonthica* are discussed.

1. Introduction

In the West-African savannah region, the productivity of cereals like sorghum (*Sorghum bicolor* (L.) Moench) and maize (*Zea mays* L.) are hampered by various abiotic and biotic constraints. Species of the plant-parasitic genus *Striga* (Orobanchaceae) represent the largest single biological constraint to food production in Africa (Hearne, 2009; Parker, 2009). In northern Cameroon, *Striga hermonthica* (Del.) Benth. is the most destructive and persistent crop pest, though farmers consider it a lesser constraint compared to soil fertility (Ayongwa et al., 2010). In former times, *S. hermonthica* was controlled by shifting agriculture, where short periods of cropping were followed by bush fallow periods, which restored soil fertility and acted as a break in the weed cycle (De Rouw, 1995), including the build-up of the parasitic weed seedbank. Shorter fallows without adequate nutrient replenishment due to increased pressure on the land resulted in lower soil fertility. This process was exacerbated by a shift from cereal – legume rotation or intercropping to cereal mono-cropping. Both the decline in soil fertility and the cereal mono-cropping resulted in the build-up of *S. hermonthica* (Abunyewa and Padi, 2003). Because of the linkage between poor soil fertility and *S. hermonthica*, approaches that only control *S. hermonthica* but neglect soil fertility do little to restore on-farm productivity to levels that make farming sustainable (Ransom, 2000; Sauerborn et al., 2003).

Because mineral fertilisers are unavailable to or too expensive for resource-poor farmers, and because the sandy soils of the savannah region are prone to leaching, organic resources are a necessary addition to inorganic fertilisers (Bationo et al., 2007). At present, only small amounts of crop residues are returned to the soil. In northern Cameroon, almost all residues are used as fodder, cooking fuel or building material and therefore removed from the fields. Organic amendments also directly affect *S. hermonthica* dynamics. *S. hermonthica* infestation decreased with increasing soil organic matter levels (Samaké et al., 2005; Sauerborn et al., 2003). However, these studies did not provide insight in the underlying mechanisms. Sherif and Parker (1988) found that chicken manure at high application rates (15 t ha^{-1}) delayed *S. hermonthica* emergence on sorghum, but that other organic manure sources with lower nitrogen concentration had no effect. Leaf litter of nitrogen-fixing legumes was also effective in suppressing *S. hermonthica* and in increasing cereal yields (Gacheru and Rao, 2001; Weisskopf et al.,

* Corresponding author. Tel.: +31 317 483079; fax: +31 317 485572.
E-mail address: tjeerdjan.stomph@wur.nl (T.J. Stomph).
1 Present address: P.O. Box 44, Dschang, Cameroon.

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2009). However, Ikie et al. (2007) showed that chicken manure (applied at 100 kg N ha^{-1}) enhanced *S. hermonthica* emergence, whereas Smaling et al. (1991) reported that neither farmyard manure nor mineral fertiliser significantly reduced *S. hermonthica* infestation.

Kranz (1999) noted beneficial effects of organic amendments and suggested that both high-quality litter and low-quality litter are beneficial. However, the way organic matter of different quality affects the interactions between cereals and *S. hermonthica* is unknown. We focus the description of organic matter quality on its C:N ratio; where-in high-quality organic matter has a low C:N ratio, and low-quality organic matter a high C:N ratio. The higher mineralisation rate of the former will also make essential nutrients (N, P, K) more rapidly available. Ayongwa et al. (2011) could not confirm several potential beneficial effects of low-quality organic matter on soil properties that contribute to *S. hermonthica* control (improved water-holding capacity, lower temperature, release of ethylene that induces suicidal germination of *S. hermonthica* seeds). We hypothesised that the major effect of high-quality organic matter on *S. hermonthica* seed mortality was due to enhanced nutrient release leading to an also enhanced biological activity and thereby decomposition of *S. hermonthica* seeds. Here we expand on the role of organic amendments on sorghum productivity and *S. hermonthica* dynamics, and compare amendments of various qualities with nitrogen fertiliser. We tested the impact of organic by-products of cotton of different qualities under conditions of low and high *S. hermonthica* pressure on performance of both sorghum and *S. hermonthica*. We also tested for effects under continuous cropping and after two years of bare fallow. Fallowing is used in the traditional farming systems, in order to regenerate soil fertility thereby also controlling *S. hermonthica* (Sauerborn et al., 2003). Under the current land pressure farmers are increasingly using short fallow periods (Ayongwa et al., 2010; Dugje et al., 2008). Research on millet systems has also indicated the productivity after short fallow ranging from 2 to 7 years is roughly the same (Samaké et al., 2006). In this research a two-year fallow was also used to fit the treatment with the available three years for experimentation. More specifically we tested the following hypotheses: (1) The beneficial effect of these by-products can be completely described by reference to nitrogen release during decomposition; (2) Amendments of high quality will have a direct negative impact on *S. hermonthica* severity and incidence, while organic amendments of low quality will increase *S. hermonthica* numbers, through a positive effect on sorghum performance; (3) The effect of organic amendments on sorghum yield increase depends on the degree of *S. hermonthica* infestation; (4) The above-mentioned effects of organic amendments are larger under continuous sorghum cropping than after fallowing.

2. Material and methods

2.1. Experimental design and layout

The experiments were carried out in Djallingo village, northern Cameroon North Province, 15 km south of Garoua, approximate coordinates of the field were 9°14″45′N, 13°27″30′E. The field experiment was a three-factorial experiment with 28 treatments ($2 \times 2 \times 7$) in a Randomised Complete Block Design with five replications:

Factor 1 (*S. hermonthica*, 2 levels), either high or low-level infected[2] soil.

[2] In this paper the terms infection (level) refer only and specifically to the density of Striga seed in the soil. The terms infestation (level) refer to the number of Striga plants in a plot or on a sorghum plant.

Factor 2 (Cropping practice, 2 levels), three years of continuous sorghum cropping or two years bare fallow followed by a single year of sorghum.

Factor 3 (Soil amendment, 7 levels), 6 t ha^{-1} of organic amendment consisting of Cotton Seed Cake (CSC – high quality material) and/or Cotton Milling Waste (CMW – low-quality material) in 5 different combinations (Table 1), a control (no organic or inorganic amendment) or 120 kg ha^{-1} nitrogen (as urea).

Each experimental unit was 6 m $\times$ 4 m = 24 m^2, crop spacing was 75 cm between rows and 20 cm within rows and an inter-plot spacing of 1 m. This gave 8 crop rows of 4 m long with 160 sorghum plants. Data were collected from 96 sorghum plants in the middlemost rows, *i.e.* from an area of 3.2 m by 4.5 m (14.4 m^2).

The field physical and chemical characteristics varied slightly over the blocks (Table 2). Soil and organic amendments were chemically analysed at the IITA laboratory in Ibadan. Both in soil and organic amendments nitrogen was determined with the Kjeldahl method and carbon with the Walkley and Black method (Anderson and Ingram, 1993).

2.2. Management practices

The experiment was run for three successive cropping seasons (June to November of 2000, 2001, and 2002) and treatments were repeated on the same plot each year, with changes made only in the fallow treatment. Fallowed plots were kept bare by weeding during 2000 and 2001 and cropped under sorghum in 2002. In all plots a high *S. hermonthica* seed density was present as the field had been cropped by the owner (farmer) with sorghum for the three preceding years, while the crop had suffered from a severe *S. hermonthica* infestation.

Low-*S. hermonthica* plots were created by treating the plots twice with 99.9% grade ethylene at the start of the rainy seasons of 2000 (17 and 30 May) and 2001(19 June and 6 July) each time following a rainfall of more than 30 mm, a treatment adapted from Eplee and Norris (1987). Sorghum was sown 14 days after the second gas injection, to avoid attachment of *S. hermonthica* seeds that had germinated in reaction to ethylene. The buds of flowering *S. hermonthica* plants were nipped to avoid seed setting. High-*S. hermonthica* plots were created by additionally infecting plots at the start of the 2000 rainy season. These plots were infected at a rate of 3000 seeds per sowing hole (Berner et al., 1997). *S. hermonthica* plants were allowed to flower and produce and shed seeds.

Four to five sorghum seeds of the *S. hermonthica*-sensitive variety CK 60B (Olivier et al., 1991, 1992, Rodenburg et al., 2006a) were sown and thinned to 1 plant per sowing-hole 14 days later.

All plots received a basal dose of superphosphate (P_2O_5) and potassium chloride (K_2O) of 40 kg ha^{-1}. The urea treatment with 120 kg N ha^{-1} was split into two doses: 90 kg N at thinning and 30 kg just after weeding, 4 weeks after sowing. Organic matter was

Table 1
Organic amendment treatment combinations. N mass fraction of cotton seed cake (CSC) was 73.7 mg g^{-1}, that of cotton milling waste (CMW) 9.6 mg g^{-1}. N release after one and three months calculated on the basis of MiNiP (Janssen, 1984, 1996). Negative number refers to N immobilisation. N release for mixtures calculated on the assumption of an additive effect. See text for details.

CSC (t ha^{-1})	CMW (t ha^{-1})	C:N ratio	N released in 1 months (kg ha^{-1})	N released in 3 months (kg ha^{-1})
6	0	6.8	183	342
4.5	1.5	8.7	135	259
3	3	12	86	177
1.5	4.5	19.7	38	93
0	6	52.1	−11	11