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Are pest regulation and erosion alleviation services conflicting or synergistic? Lessons from Sahel pearl millet

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ABSTRACT

From 2010 to 2011 in Niger, the effects of a wind erosion-alleviating practice, i.e. mulching pearl millet fields with crop residue, on populations of and damage induced by millet stem borer (MSB), head miner (MHM), and head scarab (MHS) were studied. Significant differences in the survival of MSB diapausing larvae in millet stems at the end of the dry season were found at both Sadore and Doukoudoukou. At Sadore, mean MSB larval survival in the treatment where stems were exported at harvest and stored on platforms (treatment 1) was 1.2/stem, i.e. significantly higher than in all other treatments. Survival was between 0.1 and 0.2 larva in treatments 2 (with millet stems left standing from harvest throughout the dry season) and 3 (with millet stems flattened toward the end of the dry season, four months after harvest). It was less than 0.1 larva in treatments 4 (with millet stems flattened in the middle of the dry season, two months after harvest) and 5 (with millet stems flattened at the beginning of the dry season, at harvest). At Doukoudoukou, mean MSB larval survival in treatment 1 was 0.14/stem, i.e. significantly higher than in treatments 4 and 5 (0.02–0.03 larva), with intermediary findings obtained in treatments 2 and 3 (0.04–0.08 larva). The population and biomass of diapausing MHM pupae and of MHS larvae in the soil were low at both locations, and not affected by crop residue management. Thus, crop residue management whereby stems were left standing until the end of the dry season did not enhance control of millet head pests via increased predator activity, while it increased MSB survival in stems.

1. Introduction

In the Sahel, there is a major soil erosion problem due to winds at the time of the dry season to rainy season shift (Rajot et al., 2009). On sandy soils wind can also damage sown millet crops. Several management practices have been implemented or proposed to alleviate this erosion and thus contribute to soil conservation and pearl millet crop protection. In earlier studies conducted by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Niger, borders of the perennial grass *Andropogon gayanus* were shown to efficiently protect millet against violent winds (Renard and Vandenbelt, 1990), although there were also contradictory reports (Michels et al., 1998).

ICRISAT's research also highlighted positive effects of mulching and leaving millet straw in fields after harvest to curb soil erosion (Michels et al., 1998) and analyzed the benefits of farmers measures to reduce wind erosion, including mulching (Bielders et al., 2004). On the other hand, several studies have highlighted the impact of millet crop (stem) residue management on the survival of diapausing millet stem borer (MSB = *Coniesta ignefusalis*) larvae and carry-over of the pest populations (Ajayi, 1990; Bouchard et al., 1993; Youm et al., 1996).

Pest control is sometimes considered an ecosystem service per se (Millennium Ecosystem Assessment, 2003). It contributes to food/biomass production, which is an essential service in terms of agroecosystem sustainability. We conducted trials in Niger from 2010 to 2011 to determine whether measures geared toward supporting ecosystem services of soil conservation, as well as pest regulation, were synergistic or conflicting. They were aimed at assessing the impact of millet crop residue management on the survival of the MSB and the millet head miner (MHM = *Heliocheilus albipunctella*), along with that of the millet head scarab beetle

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(MHS = *Rhinyptia infuscata*), another highly damaging pest of pearl millet in the Sahel, particularly in Niger (Youm, 1995), which has soilborne stages like the MHM.

2. Materials and Methods

2.1. Impact of millet crop residue management

In 2010, at both Sadore and at the Doukoudoukou Seed Multiplication Center (13°51′0″ N, 6°19′60″ E), a trial was conducted to assess the impact of millet crop residue management on the survival of the MSB and other insect pests of pearl millet and their impact. The pearl millet cultivar used was ICMV IS 99001.

There were five treatments with four replications using a randomized complete block design: (1) millet stems exported at harvest; (2) millet stems left standing from harvest all through the dry season; (3) millet stems flattened toward the end of the dry season (four months after harvest); (4) millet stems flattened in the middle of the dry season (two months after harvest); (5) millet stems flattened at harvest). The experimental millet plots were 12.8 m × 12.8 m (spacing of 0.80 m × 0.40 m, at ca 6–8 seeds per hill, namely ca 3.5 kg/ha). Superphosphate (ca. 18% P_2O_5) was broadcast at the rate of 200 kg/ha. This fertilization was based on the expected deficit in phosphorous in the Sadore plot used for this trial, which had been under fallow (and thus not fertilized), at least for the 25 years of existence of the ICRISAT station.

Two 1 m^2 quadrats were harvested and the extent of MSB (counts of larvae per stem), of MHM (counts of mines per spike) and of MHS (counts of damaged spikes) were assessed. All above- and below-ground macrofauna (including soilborne stages of MHM and MHS, i.e. pupae and white grubs, respectively) were sampled on the same quadrats, using a method derived from TSBF (Anderson and Ingram, 1993), down to 30 cm depth (which generally corresponded to the compaction surface), as described in Ratnadass et al. (2013). They were counted and weighed according to taxa. Grain harvested in these quadrats was also weighed, along with that of the rest of the plot, and yield per ha calculated. At millet harvest, soil samples were taken using a 5 cm-diameter cylinder, from the surface (0- to 15-cm) layer at the center and in each half diagonal of each plot. The five 0.295 L-samples were pooled and reduced to a manageable sample by coning and quartering. Analyses were performed by ICRISAT's Soil Laboratory at Sadore: pH-H_2O and pH-KCl (1:2.5); organic *C* (%); total *N* (mg kg^{-1}); Bray-P1 (mg P kg^{-1}); ECEC (cmol$^+$ kg^{-1}).

At the end of the dry season (in May 2011), after all treatments had been applied, MSB survival was assessed on another two 1 m^2 quadrats per plot, and above- and below-ground macrofauna were similarly sampled, counted and weighed.

2.2. Data analysis

Data were analyzed using the ANOVA module of XLSTAT (Addinsoft, 2011), after square root transformation for macrofauna counts, followed by mean comparison using Newman–Keuls method.

3. Results

At both Sadore and Doukoudoukou, soil compositions were homogeneous, with soil at Sadore characterized by a very low phosphorus content, and that of Doukoudoukou by very low carbon and nitrogen contents (Table 1).

Grain yield at the 2010 harvest was homogeneous at both locations, whereas MSB and MHM impacts were high and homogeneous at Sadore, but lower and more heterogeneous at Doukoudoukou. On the other hand, the extent of millet head damage by MHS was high at both locations, although higher at Doukoudoukou (Table 2). Significant differences were found in the extent of MSB (diapausing) larval survival in millet stems at the end of the dry season at both locations (Figs. 1 and 2).

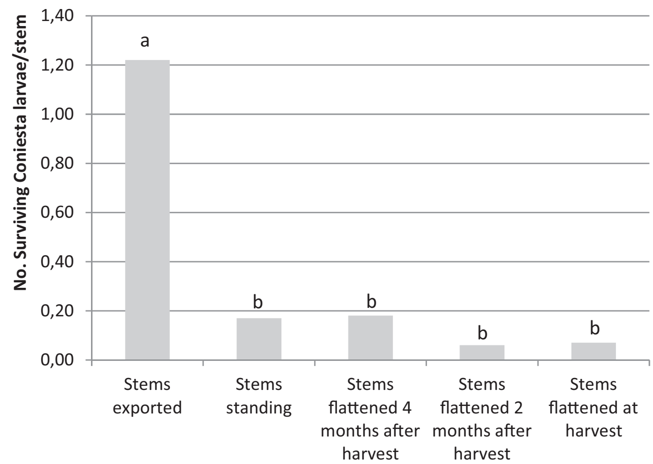

Fig. 1. MSB (Coniesta) survival in millet stems recorded at Sadore at the end of the dry season (May 2011). Bars with the same letters are not significantly different at $P < 0.05$ according to Newman–Keuls test.

At Sadore, mean survival of MSB larvae in exported stems stored on platforms (treatment 1) was 1.2/stem, significantly higher than in all other treatments. It was between 0.1 and 0.2 larva in treatments 2 (with millet stems left standing from harvest throughout the dry season) and 3 (with millet stems flattened toward the end of the dry season, four months after harvest). It was less than 0.1 larva in treatments 4 (with millet stems flattened in the middle of the dry season, two months after harvest) and 5 (with millet stems flattened at the beginning of the dry season, at harvest).

At Doukoudoukou, mean survival of MSB larvae in exported stems stored on platforms (treatment 1) was almost tenfold lower than at Sadore. It was 0.14 larva/stem, i.e. significantly higher than in treatments 4 and 5 (0.02–0.03 larva), whereas intermediary results were obtained in treatments 2 and 3 (0.04–0.08 larva), i.e. not significantly different from treatment 1 on the one hand, or from treatments 4 and 5 on the other.

Meanwhile, despite the high MHM numbers at harvest at Sadore, the population (Table A) and biomass (data not shown) of diapausing soilborne MHM pupae were low, although slightly higher than at Doukoudoukou (Table A). The same trend was observed for MHS larvae and millet head damage at Sadore, while at Doukoudoukou, slightly higher damage by MHS meant that there was higher soilborne MHS larval populations (Table A).

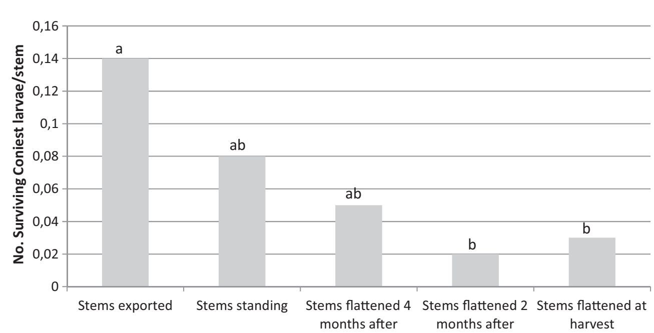

Fig. 2. MSB (Coniesta) survival in millet stems recorded at Doukoudoukou at the end of the dry season (May 2011). Bars with the same letters are not significantly different at $P < 0.05$ according to Newman–Keuls test.