Intercropping increases parasitism of pests

As part of a programme for controlling lepidopteran stem-borers in cereal crops in Africa, we have investigated the effectiveness of combined cropping regimes of cultivated and wild plants for reducing stem-borer damage. Intercropping with the non-host molasses grass, *Melinis minutiflora*, significantly decreased levels of infestation by stem-borers in the main crop and also increased larval parasitism of stem-borers by *Cotesia sesamiae*. Volatile agents produced by *M. minutiflora* repelled female stem-borers and attracted foraging female *C. sesamiae*. One of the volatile components released by intact *M. minutiflora* which attract parasitoids is also produced by herbivore-damaged plants and is implicated more widely as a cue for stimulating predation and parasitism.

Maize (*Zea mays*) and sorghum (*Sorghum bicolor*) are the most important cereal crops for the people of Africa. Lepidopteran stem-borers are ubiquitous pests that attack these crops throughout their growth stages and the larvae cause damage ranging from 20 to 80% loss of yield. One approach to pest control in resource-poor regions is to develop management systems

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Table 1 Response of *C. sesamiae* to plant or plant extract

Stimulus	Response		Significance (*P*)
	Treatment	Control	
Live plant (30 g)	39	7	< 0.005
Extract (0.2 mg)	22	18	Not significant
Extract (2 mg)	32	18	< 0.05
Extract (20 mg)	44	9	< 0.005
Nonatriene (0.1 mg)	35	18	< 0.05
Nonatriene (1 mg)	36	14	< 0.005

Response of female *Cotesia sesamiae* in the Y-tube olfactometer to *Melinis minutiflora* (live plant or extract) and (*E*)-4,8-dimethyl-1,3,7-nonatriene. Number of females choosing each 'arm' of the Y-tube is given. Control was clean air. 1 mg plant extract≈20 g (wet mass) plant material.

using the 'push–pull' or stimulodeterrent diversionary strategy[1], whereby insects are repelled from a harvestable crop and simultaneously attracted to a 'discard' or 'trap' crop. For maximum efficacy, these systems should also exploit natural enemies, particularly hymenopteran parasitoids, which can be important in suppressing pest populations[2]. Indeed, reductions in such beneficial organisms frequently trigger pest outbreaks[3].

To develop a diversionary strategy for small-scale African cereal production, we assessed a range of cultivated and wild plants in the Gramineae family (Poaceae) in field trials in Kenya for susceptibility to stem-borers, particularly the indigenous *Busseola fusca* (Lepidoptera, Noctuidae) and the introduced *Chilo partellus* (Lepidoptera, Pyralidae). In these trials, molasses grass showed no colonization by stem-borers. Further, volatiles extracted by hydrodistillation of the plant repelled gravid female stem-borers in a laboratory oviposition assay (for *C. partellus*, eggs laid per filter-paper disc: control 40.9, 100 μg *M. minutiflora* extract 2.2; $P < 0.005$, $n = 8$). In field trials at Mbita Point on Lake Victoria, *M. minutiflora* planted in alternate rows with maize significantly reduced stem-borer infestation of the main crop (damaged maize plants: single crop 39.2%, intercropped with *M. minutiflora* 4.6%; $P < 0.01$). We also saw a significant increase in parasitism by the larval parasitoid *C. sesamiae* (Hymenoptera, Braconidae) (parasitized larvae in maize: single crop 5.4%, maize with *M. minutiflora* intercrop 20.7%; $P < 0.01$).

To identify the chemicals mediating this behaviour of stem-borers and parasitoids, we isolated volatiles from live *M. minutiflora* plants by entrainment into porous polymer[4]. Electrophysiologically active components in the solvent-eluted samples were located by coupled gas chromatography and electroantennography[5]. We tentatively identified active peaks by gas chromatography–mass spectrometry and confirmed their identity by co-injection with authentic compounds on two columns of different polarity, and using behavioural studies[6]. Characterized semiochemicals included α-terpinolene, the ocimene isomers, β-caryophyllene, humulene and (*E*)-4,8-dimethyl-1,3,7-nonatriene.

Production of some of the compounds released by intact *M. minutiflora* can also be induced in plants damaged by herbivorous insects[7–9]. The nonatriene in particular has been implicated as an 'SOS' signal recruiting predators and parasites[10]. The presence of such compounds in the *M. minutiflora* intercropping system could provide an explanation for the increased parasitism observed. In behavioural assays using a Y-tube olfactometer[6], we showed that foraging female *C. sesamiae* were indeed attracted to live *M. minutiflora* plants and also responded in a dose-dependent manner to the hydrodistillation extract (Table 1), and to the nonatriene alone.

The prospects for understanding and exploiting the interaction of hymenopteran parasitoids with their hosts have advanced rapidly, particularly with the discovery that semiochemicals released during herbivore damage can stimulate parasitoid foraging[11–13]. Our study suggests that intact plants with an inherent ability to release such stimuli could be used in new crop protection strategies.

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