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Response of weeds and soil microorganisms to imazaquin and pendimethalin in cowpea and soybean

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A B S T R A C T

Herbicides applied to combat weeds and increase crop yields may also have undesired effects on beneficial soil microorganisms. Field studies were conducted in 2005 and 2006 in Zaria, Nigeria, to evaluate the response of weeds and soil microorganisms to imazaquin applied at 0.05, 0.10, 0.20 and 0.40 kg a.i./ha and pendimethalin applied at 1.0, 2.0, 4.0, and 8.0 kg a.i./ha in cowpea and soybean. Hoe-weeded and unweeded (no herbicide) plots were controls. Both herbicides significantly reduced weed biomass in both crops, when compared to the unweeded control, which had the highest weed biomass at all sampling dates. Treatments with 0.40 kg a.i./ha of imazaquin, 2.0 and 4.0 kg a.i./ha of pendimethalin, and the hoe-weeded control, had the highest cowpea grain yield. The unweeded control had the lowest grain yield which was comparable to that in all other herbicide treatments. All treatments except 4.0 and 8.0 kg a.i./ha of pendimethalin had higher soybean grain yield than the unweeded control. Soybean yield was lowest in the unweeded control, and treatments that received 4.0 and 8.0 kg a.i./ha of pendimethalin. All rates of imazaquin gave similar soybean grain yields that were 29–41% higher than that from pendimethalin. The hoe-weeded control had the highest yield, which was 79% more than that in the unweeded control. Higher rates of imazaquin and pendimethalin reduced nodulation, nitrogen fixation, and vesicular arbuscular mycorrhizal (VAM) fungi colonisation in both crops. VAM fungi species diversity and species richness in cowpea rhizosphere soil and species diversity in soybean rhizosphere soil were reduced relative to the controls due to application of both herbicides with the rates of 0.10, 0.20, and 0.40 kg a.i./ha of imazaquin and 8.0 kg a.i./ha of pendimethalin being significantly effective.

1. Introduction

Soybean and cowpea are important legumes for millions of people in sub-Saharan Africa (Langyintuo et al., 2003). Soybean is the second most important crop after maize in the Guinea savanna of Nigeria, where the crop is grown on over 650 000 ha annually (Carsky et al., 1997; FAO, 2007; Sanginga, 2003). Soybean can be processed into high protein food supplements, edible oils, soybean meal for livestock and has many other industrial uses. Soybean also has some functional traits that have been shown to be of benefit to human health, for example, isoflavones which lower cholesterol, reduce risks of cardiovascular diseases, diabetes, and osteoporosis (Cui et al., 2004). Soybean is also adapted to stressful environments such as drought, water logging, acid soils, and a wide range of insects and diseases.

About 8 million ha of cowpeas are grown in West and Central Africa with Nigeria, as the highest producer. Annually in Nigeria, cowpea is planted on about 5 million ha, producing over 2.4 million tons (FAO, 2007). Cowpea plays a critical role in the lives of millions of people in Africa as a major source of protein that nutritionally complements the staple cereal and tuber crops (Muleba et al., 1997; Quin, 1997; Singh et al., 2003). The fodder and husks, which contain about 18% protein, are major sources of quality fodder for livestock particularly in the dry season when other feed resources are in short supply. Cowpeas are adapted to stressful environments where other crops often fail or cannot grow well, such as the less fertile soils and zones where rainfall is low and erratic.

Legumes improve soil fertility through nitrogen (N) fixation and organic matter production (Dakora and Keya, 1997; Duke, 1990; Reynolds et al., 1993), and contribute to the sustainability of cropping systems by reducing the need for expensive mineral N

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Nomenclature

Cowpea (*Vigna unguiculata* L. Walp)
Soybean (*Glycine max* L. Merill)

fertilizers. Bagayoko et al. (1998) reported that cowpea could supply 35–40 kg N/ha in a cowpea-millet rotation. Soybean in rotation with cereals provided residual N in excess of 150 kg N/ha (Sanginga et al., 1996). In highly-weathered tropical soils, N is often the most limiting nutrient. In West and Central Africa, legumes are usually intercropped with cereals. Evidence of N-transfer from legumes to cereals has been demonstrated in intercropping studies (Bandyopadhyay and De, 1986; Patra et al., 1986). Some varieties of soybean also cause suicidal germination of *Striga hermonthica* Del. Benth, a very serious parasite of cereals, and thus ultimately improve yields of subsequent cereals (Schulz et al., 2003).

Weeds are one of the major constraints in legume production. Yield reductions of 13–82% have been reported in cowpea and 65% in soybean from weed competition (Li et al., 2004; Tripathi and Singh, 2001). Weed control also consumes a lot of resources to prevent potential yield losses (Chikoye et al., 2006). Labour-based weed management used by most small holder farmers is time-consuming, expensive, and inefficient (Chikoye et al., 2006). Furthermore, labour may not be available at the peak periods of requirement. Chemical control is a cheaper and more effective option (Chikoye et al., 2004), which improves crop yields and grain quality (Knott, 1985; Schnelle and Hensley, 1990). However, overuse of herbicides may have adverse effects on beneficial soil microorganisms, such as rhizobia and vesicular arbuscular mycorrhizal (VAM) fungi (Burnet and Hodgson, 1991), which contribute to increasing N and phosphorus availability in the soil. Herbicide-induced reduction in metabolism of nodule bacteria, nodulation, and N-fixation have been reported (Bollich et al., 1985; Eberbach and Douglas, 1983; Maftoun et al., 1982; Pahwa and Prakash, 1992; Singh and Wright, 2002). Sawicka and Selwet (1998) reported that imathezapyr and linuron reduced fungi and root-nodule bacteria nitrogenase activity. In another study, Mallik and Tesfai (1985) found that trifluralin, alachlor, glyphosate, and metribuzin adversely affected nodulation and N-fixation in soybean when applied at rates 5 and 10 times more than the recommended dosages. In other reports, however, field application of certain herbicides at 500 times the recommended rates did not affect rhizobial growth and nodulation (Gonzalez et al., 1996). These reports suggest that adverse herbicide effects on nodulation and N-fixation may be controlled by a strong herbicide by legume genotype interaction. Imazaquin and pendimethalin are recommended for weed control in cowpea and soybean in West Africa. There is little information available on the effects of these herbicides on rhizobia and VAM fungi in these legumes in the tropics. The objectives of this study were to investigate the effects of imazaquin and pendimethalin on weeds, N-fixing bacteria, VAM fungi, and yields of soybean and cowpea.

2. Materials and methods

2.1. Description of experimental site

Field trials for each crop were conducted at the Ahmadu Bello University/Institute for Agricultural Research farm in Zaria (11°13′ N, 7°12′ E), Nigeria in 2005 and 2006. The site was in the northern Guinea savanna, which has mean annual temperature of 30 °C and annual precipitation of about 1000 mm. The weed flora in the experimental field consisted mostly of seedlings of *Mariscus alternifolus* Vahl., *Kyllinga squamulata* Thonn. Ex Vahl. and *Cyperus* spp. and annual weeds dominated by *Ageratum conyzoides*. The characteristics of soil at the trial sites are presented on Table 1.

2.2. Procedures

The land was ploughed and ridged using a tractor in June 2005 and July 2006. Each trial consisted of three replicates in a randomised complete block design, with four rates each of imazaquin (0.05, 0.10, 0.20 and 0.40 kg a.i./ha) and pendimethalin (1.0, 2.0, 4.0 and 8.0 kg a.i./ha). Hoe-weeded and unweeded (no herbicide) treatments were controls. The plots were 22.5 m^2 (6 m long × 3.75 m wide). Seeds of cowpea variety 'IT90K–277–2' and soybean 'TGX 1448–2E' were obtained from IITA, Ibadan, Nigeria. The two varieties are officially released for commercial use in Nigeria. Two cowpea seeds were sown per hill on 2 August 2005 and 24 July 2006, on ridges spaced 75 cm apart with an intrarow spacing of 25 cm. Soybean seeds were sown on 17 July 2005 and 5 July 2006 by drilling in rows spaced 75 cm apart. In both years, compound fertilizer [NPK (15:20:15)] at a rate of 10 kg N/ha, and 30 kg P/ha was applied at sowing. The herbicides were applied preemergence, one day after sowing, using a CP-3 knapsack sprayer equipped with a floodjet nozzle and calibrated to deliver 250 l/ha at a pressure of 200 kPa. At 2 weeks after planting (WAP), the seedlings of both crops were thinned. Cowpea seedlings were thinned to 1 plant per hill giving a population of 50 000 plants/ha; soybean seedlings were thinned to a spacing of 10 cm within rows giving a population of 130 000 plants/ha. Cypermethrin 10% EC at the rate of 1.0 l/ha was applied to the cowpea with a hand pumped CP 3 knapsack sprayer at weekly intervals from the onset of flowering till full pod growth to control insect pests. The hoe-weeded control plots were hoed 4 times in each year at 2-week intervals with the first weeding occurring at 2 WAP.

2.3. Data collection

Weed control was assessed using weed shoot dry biomass sampled at 4 and 8 weeks after treatment (WAT) and at crop maturity in both years. At all sampling dates, these data were assessed from four 0.5 m^2 quadrats fixed within the first half of each plot. Shoots of all weed species in each quadrat were clipped at ground level and then bulked for each plot. Weed samples were dried at 80 °C for 48 h for dry biomass determination.

The root biomass of soybean and cowpea was sampled at 50% podding stage ($R_{3.5}$) in both years to estimate nodule number,

Table 1
Soil characteristics at Zaria, Nigeria in 2005 and 2006.

Soil parameter[a]	2005		2006	
	Cowpea	Soybean	Cowpea	Soybean
% C	0.52	0.53	0.54	0.53
% N	0.04	0.04	0.05	0.05
Ca (cmol/kg)	1.86	1.92	2.42	2.70
Mg (cmol/kg)	0.66	0.64	0.92	1.03
K (cmol/kg)	0.29	0.43	0.38	0.38
Na (cmol/kg)	0.05	0.14	0.58	0.57
pH	6.3	5.9	5.6	5.4
% Sand	55	56	41	45
% Clay	12	10	16	16
% Silt	33	34	43	39

[a] Analytical procedures: Organic carbon by chromic acid digestion (Hearnes, 1984); nitrogen in soil by Kjeldahl digestion (Bremner and Mulvaney, 1982); phosphorus and exchangeable cations in soil by Mehlich 3 extraction (Mehlich, 1984); soil pH determined in water on 1:1 soil:water ratio (IITA, 1982).