Effect of organic, low-input and conventional production systems on pesticide and growth regulator residues in wheat, potato and cabbage

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Abstract

The Nafferton factorial systems comparison (NFSC) experiments facilitate the investigation of effects of, and interaction between, three production system components - a) rotational position, b) fertility and c) crop protection management - in organic, conventional and low-input crop management systems. This paper presents first results on pesticide and growth regulator residues observed over a period of two years. Residues were only detected for three (Chlormequat, Chlorothalonil and Aldicarb) of the 28 pesticides used in the experiments. As expected, residue levels were affected by the crop protection practices, but significant effects of fertility management practices were also detected. This indicates that the human health risks associated with pesticide residues may increase in low input systems which attempt to reduce the environmental impact of conventional farming systems by switching to organic matter based fertilisation regimes.

Introduction

Crops from organic cropping systems have been shown to contain no or lower levels of pesticide residues (e.g. Woese et al., 1997). However, less is known about the pesticide residue levels in other 'low input' or integrated cropping systems that focus on reducing (or omitting) mineral N, P and K fertilisers and/or chemosynthetic pesticide inputs. Also it is currently not clear to what extent fertility management and crop protection measures interact in these new low-input systems with respect to levels of pesticide residues.

Chlormequat is the most commonly used growth regulator in conventional agriculture. Recently it has been shown that chlormequat impairs fertility in male and female pigs when fed with chlormequat contaminated grain (Sorensen and Danielsen, 2006). Aldicarb is a carbamate insecticide, which has a high level of acute toxicity to humans through cholinesterase inhibition. It is readily absorbed through the gut and skin, soluble in water and has a half life of one to two weeks (Risher et al., 1987). It is detected as Aldicarb, Alidcarb sulfone and Aldicarb sulfoxide. Chlorothalonil is a broad spectrum fungicide that has been shown to be carcinogenic in rodents and is also suspected to be carcinogenic in humans (Wilkinson and Killeen, 1996).

The aim of the study presented here was to describe the effect of crop protection and fertilisation regimes on residues of chemosynthetic pesticides and growth regulators.

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Materials and methods

The Nafferton factorial systems comparison (NFSC) experiments were established to investigate effects of, and interaction between, three production system components - a) rotational position, b) fertility and c) crop protection management, that differ between organic, low input and conventional production systems. These long-term experiments were established in 2001 on a field with a uniform sandy loam soil at the University of Newcastle's Nafferton Experimental Farm, near Stocksfield, Northumberland, UK. Four separate experiments, each including two principle crop rotations (one typical for organic farming systems and one typical for conventional farming systems in North East England) have been established. In each experiment the rotational sequence starts in a different year to allow results from a variety of crops to be obtained in the same cropping year. The main crops in the NFSC experiments are wheat, barley, potatoes, cabbage, lettuce and onions. The experimental design is a split-split-split plot design with crop rotation as the main factor and crop protection and fertility management as the sub-plot and sub-subplot factors respectively (Leifert et al 2007). Conventional crop protection (CON) is applied according to the British Farm Assured (FAB) standards, and organic crop protection (ORG) according to Soil Association organic farming standards. Under conventional fertility management mineral fertiliser inputs (MIN) are applied, and composted manure inputs (MAN) under organic fertility management (Leifert et al 2007).

The analysis of pesticide residues in the experiment was performed by the Institute of Chemical Technology, Prague, CZ. For Aldicarb and Chlormequat milled homogenized wheat samples were extracted with methanol. 2 ml of crude extract was filtered through 5 µm PTFE filter into a 2 ml vial and measured by LC-MS/MS operated in positive electrospray ionisation. A Discovery C18 column with mobile phase gradient methanol-0.01 M ammonium acetate mixture was used for separation of Aldicarb and Atlantis HILIC column with mobile phase methanol-0.1 M ammonium acetate mixture (60:40, v/v) was used for separation of Chlormequat. For Chlorothalonil extraction was carried out by ethyl acetate. The crude extract was purified by automated high performance gel permeation chromatography. As a mobile phase a mixture of ethyl acetate-cyclohexane (1:1, v/v) at flow 1 ml/min was used. Identification/quantification of Chlorothalonil was carried out by GC-MS operated in selected ion monitoring mode. For separation a capillary column DB-5MS was used. The level of detection (LOD) was 4, 3 and 8 µg/kg for Chlormequat, Chlorothalonil and Aldicarb sulfoxide respectively.

In both years the significance of fertility management and crop protection, and the interaction between these two terms, was assessed using a linear mixed effects model in R (R Foundation for Statistical Computing, Vienna, Austria 2005), with block treated as a random effect, and crop protection as a fixed effect, nested within block (Pinheiro and Bates, 2000).

Results and discussion

Table 1 shows the pesticides and growth regulators that have been used in the experiment and levels of residues detected in crop samples in two cropping seasons (2004 and 2005). Residues could only be detected for three crop protection products used: the growth regulator Chlormequat, the pesticide Aldicarb and the fungicide Chlorothalonil. All three agrochemicals were detected at levels below their legal thresholds. Here it should be pointed out that the applied FAB standards aims at minimising crop protection residues by ensuring threshold based pesticide use and optimised timing of pesticides.

Table 1: Pesticides and growth regulators applied to crops in the Nafferton Factorial Systems Comparison Experiment (NFSC)

Crops	Below level of detection	Detected 2004	Detected 2005
Wheat	Chlorothalonil, Diflufenican, Epoxiconazole Fenpropidin, Fenpropimorph, Isoproturon, Mecoprop-P, Pendimethalin, Trifloxystrobin	**Chlormequat**	**Chlormequat**
Potatoes	Diquat, Fluazinam, Linuron, Mancozeb, Metalaxyl-M, Aldicarb	**Aldicarb sulfoxide, Aldicarb sulfone**	
Lettuce	Azoxystrobin, Iprodine, Propachlor	-	-
Cabbage	Azoxystrobin, Chlorpyrifos, Cypermethrin, Iprodine, Propachlor	-	**Chloro-thalonil**
Onion	Azoxystrobin, Iprodine	-	-

Table 2 shows how the residues were affected by the management systems. As expected, significant pesticide residues were only detected in crops under conventional crop protection management. Under organic crop protection the chemicals were either not detected or at very low level (10 times lower than the conventional level for Aldicarb). These traces are most likely due to spray drift and are comparable to those found in commercial organic practice (e.g. Baker et al., 2002) and attributed to cross contamination by spray drift and other factors.

Table 2: Effect of fertility management and crop protection on residues found in selected crops and years

Crop		Wheat 2004	Wheat 2005	Cabbage 2005	Potato 2004
Residue		**Chlormequat (mg/kg)**	**Chlormequat (mg/kg)**	**Chlorothalonil (mg/kg)**	**Aldicarb sulfoxide (µg/kg)**
		Main effect means			
Fertility management	MAN	0.13	0.23	0.01	0.00[1]
	MIN	0.04	0.06	0.01	4.02
Crop protection	ORG	0.00[1]	0.00[1]	0.00[1]	0.36
	CON	0.17	0.29	0.02	3.66
		ANOVA (p-values)			
Fertility management		****	****	0.81	**
Crop protection		****	**	0.17	0.29
Fertility management x crop protection interaction		****	****	0.81	0.052
Maximum Residue Level (Codex Alimentarius)		3 mg/kg for grain 5 mg/kg for wholemeal		1 mg/kg	500 µg/kg

** significant for $P<0.01$; **** significant for $P<0.0001$, [1] values below LOD are reported as zero

Unexpectedly, residue levels of some crop protection products were also shown to be affected by fertility management. While Chlormequat in wheat was detected in higher quantities under organic fertility management, Aldicarb sulfoxide was increased under conventional fertility management. A significant interaction was only detected for the growth regulator Chlormequat. When no growth regulators were applied no or very low residue levels were detected under both fertility managements. However, wheat treated with the growth regulator contained three times higher residue levels when fertilised with manure compost, than wheat grown under mineral fertiliser-based fertility management.

Conclusions

Most of the applied pesticides stayed below the level of detection using state of the art methods. The only detected agents were Chlormequat, chlorothalonil, and Aldicarb. Both Chlormequat and Aldicarb were affected by crop protection measures and fertility measures.

Three times higher levels of Chlormequat residues were found when crops under conventional crop protection were fertilised with manure-compost rather than mineral fertilisers. This indicates that the human health risks associated with pesticide residues may increase in low input systems which attempt to reduce the environmental impact of conventional farming systems by switching to organic matter based fertilisation regimes. Further research is required to understand the impact of fertilisation practices on the levels of pesticide residues.

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