Reducing weed infestation in winter wheat by sowing technique

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Abstract
Hoeing can improve weed control in cereals but this requires wider row spacing of the crop. A specific band row design may also ensure high crop yield and quality, especially at the conditions of organic farming. In order to study those effects two field experiments with winter wheat were conducted in 2005 and 2006 at the organic farming research area of the BBA. Three different row designs have been investigated: narrow (100 mm spacing), wide (400 mm) and band sowing (alternating of crop band of 400 mm and a crop-free band of 300 mm width). All plots were harrowed whereas the wide and band sown plots have additionally been hoed. Also two cultivars differing in growth habit and competitiveness were tested (Ludwig, Pegassos).
Neither harrowing nor the combination of harrowing and hoeing could reduce weed density (by analysing data before and after treatments). Also the different row spacing had no effect on weed density at late spring (257 weeds m^{-2}). However, weed growth at the same time was clearly influenced by the row spacing: Weed biomass was significantly higher in the plots with wide rows (23.1 g m^{-2}) compared to normal (8.3 g m^{-2}) and band sowing (10.5 g m^{-2}). Crop yield was highest at band sowing (7.09 t ha^{-1}) whereas the wide sown crop stand was of significant lower yield (6.18 t ha^{-1}) but highest protein content (10%). Regarding cultivar effects Pegassos was more competitive against weeds and provided also a higher yield than cultivar Ludwig.
So far, band sowing has been proved as an easily applicable sowing technique which enables the use of hoes in cereals and ensure high crop yield especially at conditions of organic farming.

Introduction

Besides preventive measures mechanical weed control, especially harrowing, is an essential tool in organically grown cereals. However, harrowing is known to be less effective against perennial weeds and other less sensitive weeds species with deep roots or erect growth habit. Such problems might be solved by using the more effective hoeing but this needs wider row spaces. In addition, wider row spacing might improve protein content in grains since nitrogen is often limited at organically grown cereals (Pommer, 2003). On the other hand, there is a risk of low competitiveness in wide crop stands, particularly if mechanical control effects are unsatisfying. Thus, different systems of row spacing designs have been tested in several studies e.g. with mulching or underseeds (Neumann et al., 2003). Based on these findings a new approach could be a crop design with alternating crop and crop-free bands as shown at Figure 1. Using hoes in the crop-free band as well as a higher crop competitiveness within the crop band are two effects in order to make weed control more effective.

Materials & Methods

2 winter wheat experiments were conducted in 2005 and 2006 (year of harvest) at the organic farming research area of the BBA . This site is characterised by a loamy soil, an average temperature of 9.0°C and a precipitation of 547 mm per year. Since this 12 ha-site has been converted to organic farming in 1995, the following 7 crops were grown in sub-plots side by side within the rotation: potatoes, winter rye, winter wheat, winter oilseed rape, summer barley, peas and clover- grass.
2 factors have been tested: crop row distance (Figure 1) and cultivar (Ludwig, Pegassos) performed in a block design with 4 replications and a plot size of 120 m^2.

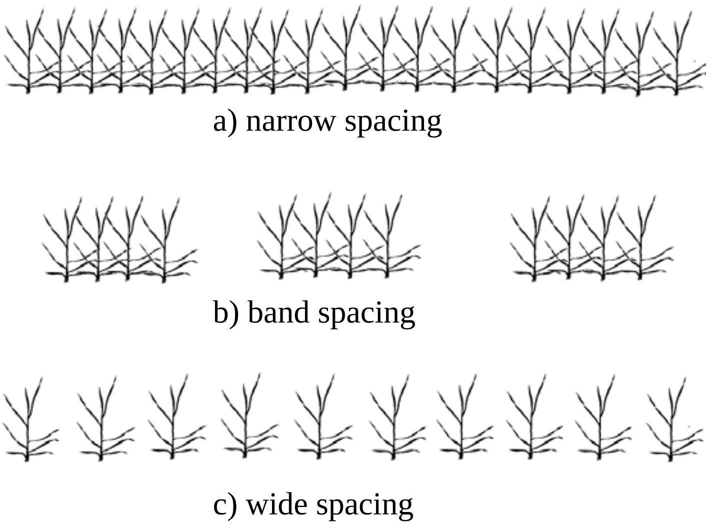

Figure 1. Scheme of row distances tested for mechanical weed control
a) narrow spacing: row distance of 100 mm
b) band spacing: bands of 4 rows (400 mm width) alternate with crop-free bands (300 mm width)
c) wide spacing: row distance of 400 mm

Pegassos is known as a cultivar fairly adapted to the conditions of organic farming. It is characterised by prostrated and large leaves whereas Ludwig can be described by a more upright growth and low competitive ability.
Because of a very high initial weed infestation it was not possible to keep plots unweeded. Depending on the weed density all plots have been harrowed two times (in 2006) and three times (in 2005), additionally the plots with the crop bands and wide rows (variant b and c) have been hoed two times. In contrast to the expectation, *Cirsium arvense* occurred in very low densities and therefore effects on this specific problem have not been investigated The seed distance within the row was the same in all treatments which resulted in different seeding rates: 350 seeds m^{-2} (narrow), 200 seeds m^{-2} (band) and 117 seeds m^{-2} (wide). The pre-crop in both years was an annual clover-grass, fertilisers and plant protection products were not applied. The main facts on trial management are given in Table 1.

Table 1. Data on trial management

	2005	2006
Sowing date of winter wheat	01.10.2004	06.10.2005
Date of harrowing	08.11.2004	-
	07.04.2005	25.04.2006
	28.04.2005	04.05.2006
Date of hoeing	04.04.2005	-
	28.04.2005	04.05.2006
Date of harvest	02.08.2005	25.07.2006

The following parameters have been assessed: ground cover and height of the crop, light penetration (PAR), weed cover, weed biomass, weed number, crop yield and crop quality.
Data were analysed by a multifactor analysis process using Statgraphics Plus, version 5.1 (Statistical Graphics Corp.) Based on all data mean values and confidence levels were calculated by considering the 3 tested factors row spacing, cultivar and year.

Results

Weed growth

The initial weed density shortly after sowing was 451 weeds m^{-2} in 2005 and 225 weeds m^{-2} in 2006. The most frequent weed species were *Lamium* spp., *Veronica* spp. *Stellaria media* and *Urtica urens*.

Weed density assessed in May was not effected by row spacing but significantly by the cultivars (Table 2). Strong interactions have also been analysed only for the factors row spacing x year ($P < 0.01$) whereas row spacing interacted weakly with cultivar.

Table 2. Effect of row spacing, cultivar and year on weed density (no. m^{-2}) and biomass (g m^{-2}) in winter wheat

Factor	Level	Weed density			Weed biomass		
		Mean	s	P-Value	Mean	s	P-Value
A) row spacing			19.9	0.9175		2.4	0.0001
	narrow	255			8.3		
	band	263			10.5		
	wide	253			23.1		
B) cultivar			16.1	0.0005		1.9	0.0474
	Ludwig	297			16.7		
	Pegassos	216			11.2		
C) year			17.1	0.4188		2.1	0.0117
	2005	266			10.4		
	2006	248			17.5		

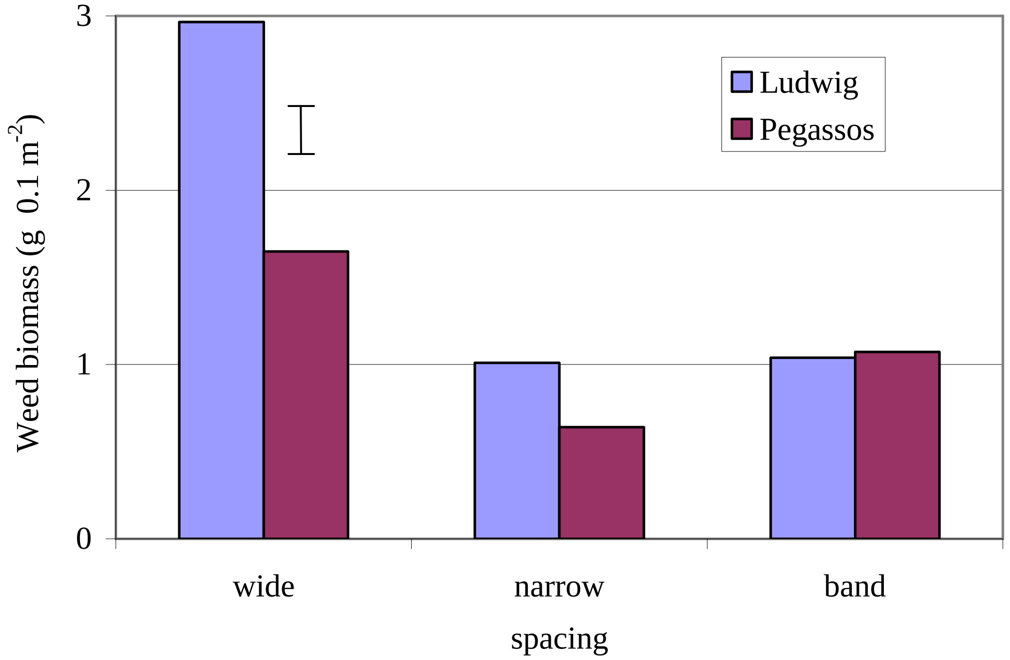

Figure 2. Effect of row spacing and cultivar on weed biomass in winter wheat (mean values and standard error of 2005 and 2006)

In contrast to these weak effects on weed density, weed biomass was significantly influenced by row spacing combined with different mechanical weed control. These different effects can be explained by the fact that many weeds will regrow or emerge soon after mechanical treatments. However, those plants are retarded especially when crop competitiveness is high like in the narrow or band sown plots.
In both years weed biomass in the wide-row plots was significantly higher than in the narrow and band crop stands. Thus, in contrast to the intention, there was no better control by additional hoeing compared to sole harrowing. Weed biomass in the narrow-spaced and only harrowed winter wheat came to the same extend as in the band-spaced variant (Figure 2). There was also a significant effect of the cultivar: Corresponding to a higher crop cover, Pegassos showed a higher weed suppression than Ludwig, especially in the wide-spaced crop stand. No differences between both cultivars have been observed at the band spacing. This is likely because 43% of the area is crop-free and therefore growing conditions within the crop bands are almost optimal.

Crop yield and quality
All tested factors had a significant effect on the yield of winter wheat (Table 3). Significant interactions have only been found for the factors cultivar and year. The highest yield was measured in the band design which indicates a high compensating ability of both wheat cultivars. This is supported by the data of the wide-sown plots: Even a seed reduction of 75% (3 of 4 rows) resulted only in a yield loss of 4.9% compared to the narrow sowing.

Table 3. Effect of row spacing, cultivar and year on crop yield (t ha^{-1}) of winter wheat and grain protein content (%)

Factor	Level	Crop yield			Grain protein content		
		Mean	s	P-Value	Mean	s	P-Value
A) row spacing			0.06	0.0000		0.06	0.0000
	narrow	6.50			8.75		
	band	7.09			9.74		
	wide	6.18			10.00		
B) cultivar			0.05	0.0000		0.05	0.0000
	Ludwig	6.40			9.82		
	Pegassos	6.79			9.18		
C) year			0.05	0.0000		0.05	0.0000
	2005	7.55			9.86		
	2006	5.63			9.14		

Similar to the weed data, Pegassos gave higher yields than Ludwig regardless row spacing and year (Figure 3). Since there was no correlation between weed biomass and crop yield, it can be assumed that other growing factors had likely a stronger impact on yield (at least for the tested conditions). There was also a significant effect on the protein content but mean values are low even for the conditions of organic farming. In both years the protein content has been increased by the band and wide sowing compared to the narrow sowing (Table 3). However, in all cases the German minimum standards of 10.5% or even 12% protein for breadmaking wheat were not fulfilled.

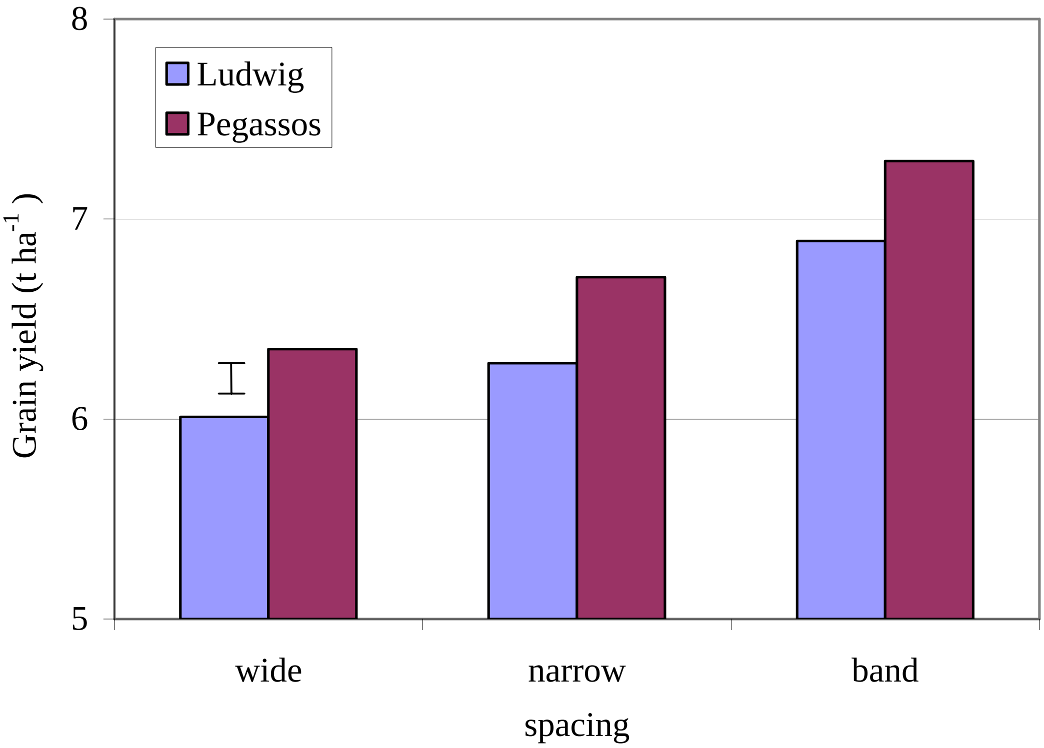

Figure 3. Effect of row spacing and cultivar on grain yield (t ha^{-1}) of winter wheat (mean values and standard error of 2005 and 2006)

Discussion

Despite the weak weed control by both harrowing and hoeing, there was a clear effect of the crop row spacing on weed growth and crop yield. As found in previous trials on the same site, mechanical control measures are of low efficacy which is typical for loamy soils with a high risk of puddling (Dierauer & Stöppler-Zimmer, 1994). In principle the band sowing design allows the use of hoes (e.g. blade or rotary hoe). However, there are several findings that certain weed species can be better controlled by burying compared to cutting (Bond & Grundy, 2003).

Focussing on the main cropping target, high crop yield and quality can be achieved by band sowing but effective weed control is required especially in the crop-free bands. So far, band sowing has been proved as an easily applicable and adjustable sowing technique. It enables the use of hoes in cereals and ensure high crop yield especially at conditions of organic farming. Despite the significant effect of row spacing on protein content, these values were not satisfying. At similar studies Schulz et al. (2003) have found stronger effects of cultivars and interactions between cultivar and sowing density.

Although weed density was high in both trials, the data indicate that crop yield is more affected by other factors rather than by weed competition. Unfortunately it was not possible to investigate the effect on perennial weeds since their abundance was very low. Therefore, trials will be repeated a third time in 2007 hoping to get further findings on the effect on *Cirsium arvense* or other perennial weed species.

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Acknowledgements

I thank Mrs Martina Kracht and Mr Werner Löhr for technical assistance.