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Seed distance in relation to row distance: Effect on grain yield and weed biomass in organically grown winter wheat, spring wheat and spring oats

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ABSTRACT

Inter-row hoeing at wide row distance can form part of a weed management strategy in which mechanical and cultural tools are combined. Crop plant distribution is a key parameter for maintaining high grain yield levels and weed suppressive ability in such a system. The influence of seed distance in relation to row distance was studied in 10 field trials on spring wheat, spring oats and winter wheat. Post-emergence weed harrowing was applied at 12–12.5 cm row distance and inter-row hoeing at 24–25, 36–37.5 and 48–50 cm distance. Three seed distances within rows were applied: (1) Normal for the region, (2) reduced to 2/3 the normal, and (3) reduced to half the normal. To obtain normal seed distance at 12–12.5 cm row distance, 400, 525 and 600 germinable seeds m^{-2} were sown in winter wheat, spring oats and spring wheat, respectively. The highest grain yields were found after weed harrowing at row distance 12–12.5 cm; 5550 kg ha^{-1} of winter wheat, 3765 kg ha^{-1} of spring oats and 3105 kg ha^{-1} of spring wheat. Inter-row hoeing at the row distance 24–25 cm, while keeping seed distance constant, lowered grain yields of all crops by 12–16%, but had no significant influence on weed biomass. Increasing the row distance from 24–25 to 36–37.5 cm reduced grain yield by 450–460 kg ha^{-1} in winter wheat and oats, while a further increase to 48–50 cm reduced yield by an additional 450–520 kg ha^{-1} in all crops when averaged over seed distances. At row distance 24 cm and wider, grain yield of winter wheat and oats increased more when the seed distance was reduced from normal to 2/3 of normal than when reduced from 2/3 to half the normal distance. In inter-row hoed winter wheat and spring oats, weed biomass increased with increasing row and seed distance. Within the range of seed distances used in this study, a reduction to half of normal was considered as the most profitable when these crops are sown at row distances 24 cm or wider. There was no indication that seed distance in spring wheat should be changed when using wide row distances. Increased row and seed distances improved the content of gluten and reduced the content of starch in wheat grain, while protein content was increased in the grain of all crops . The response to treatments in terms of grain content of ergosterol was inconsistent between winter and spring wheat.

1. Introduction

A frequent consequence of the transition from conventional to organic farming is increasing weed infestation that develops into a major problem (Cavigelli et al., 2008; Corbin et al., 2010). This constitutes one of the primary constraints on production (Turner et al., 2007). In organic farming the use of herbicides is prohibited, so the weed control tools consist of cultural, biological and mechanical means (*cf.* Hatcher and Melander, 2003; Melander et al., 2005). Combination of various measures into weed management strategies is essential for the economic profitability of organic production. In successful strategies, the crop rotation used is of fundamental significance (Albrecht, 2005), as is the sequence of crops in the rotation (Eyre et al., 2011). In long-term organic rotations, the need for weed management is higher when annual crops are the main component, while inclusion of a perennial forage crop may reduce populations of broadleaved weeds in the seedbank (Wortman et al., 2010).

In stockless organic farming systems, the crop rotation is often based on annual crops, primarily cereals that tolerate physical weed management. When sown at narrow row distance, post-emergence weed harrowing may be rather efficient, providing 60–85% weed control after the first pass and 84–98% after three passes (Rasmussen et al., 2010). However the efficiency varies between, *e.g.* weed species (Lundkvist, 2009) and timing of

Abbreviations: Row distance, 12.0–12.5 cm (RD_{12}), 24.0–25.0 cm (RD_{24}), 36.0–37.5 cm (RD_{36}) and 48.0–50.0 cm (RD_{48}); Seed distance, Normal for the region (SD_1), 2/3 of the normal ($SD_{2/3}$), half the normal ($SD_{1/2}$).

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Table 1
Location of the experimental sites and range values of characteristics of topsoil (0–30 cm) in the trials of winter wheat, spring oats and spring wheat.

	Winter wheat	Spring oats	Spring wheat
Number of trials	3	3	4
Latitude	56°3.5′N-59°17′N	56° 11′N-59° 13′N	58° 21′N-59° 26′N
Longitude	13°58′E-15°3.6′E	13°45′E-15°11′E	12°38′E-15°29′E
pH (H_2O)	5.9–7.2	6.1–6.7	6.1–6.6
Organic matter (%)	2.4–4.2	2.2–8.4	3–6.3
Sand (%)	9–54	16–44	8–28
Silt (%)	19–51	42–68	27–51
Clay (%)	21–40	14–16	21–51

application (Rasmussen et al., 2008). Cultivation of cereals at wide row distances that allow inter-row hoeing provides an additional possibility for mechanical weed control. Inter-row hoeing can be carried out over a longer period of time than weed harrowing and is thereby more flexible to use. Besides serving as a weed management tool, hoeing may improve crop conditions by breaking soil crusts and aerating the soil (Leblanc and Cloutier, 2001) and soil cultivation may also enhance nitrogen mineralisation (Becker and Böhrnsen, 1994). The negative effects of physical weed management relate to the risk for damaging crop plants as well as the weeds and use of an optimal seed rate is essential (Rasmussen et al., 2008, 2009).

Plant stand design is a key parameter for the outcome of weed suppression and grain yield quantity and quality (Kolb et al., 2010; Kristensen et al., 2008; Olsen and Weiner, 2007; Weiner et al., 2001). Seed rates recommended by seed companies are optimised for the row distance normally used, which in Sweden is 12–12.5 cm. Increasing the row distance without a seed rate reduction decreases the distance between individual seeds, thereby increasing intraspecific and inter-specific competition between plants. Based on common garden experiments, Håkansson (2003) describes the relationship between seed rate and row distance in relation to grain yields of cereals and weed incidence. A common assumption is that seed rate should be reduced when row distance is increased, although the optimal magnitude of the reduction is poorly known.

The aims of the present study were to assess the influence of seed rate in relation to row distance on (i) grain yield quantity, (ii) grain quality and (iii) weed biomass and abundance in organically-grown spring wheat, spring oats and winter wheat that had been exposed to different mechanical weed control treatments. Inter-row hoed cropping systems sown with different sowing seed distances at 24–25 cm row distance or wider were mutually compared. In addition, at normal seed distance, a weed harrowed cropping system sown at 12–12.5 cm row-distance was compared with the inter-row hoed system sown at 24–25 cm row distance.

2. Material and methods

2.1. Experimental sites and crop species

A total of 10 field experiments were carried out in southern and central parts of Sweden during the period 2006–2008. In spring oats (*Avena sativa* L., *cv*. SW Sang), two experiments were performed in 2006 and one in 2007, while in spring-sown wheat (*Triticum aestivum* L., *cv*. SW Dacke), two experiments were performed in 2007 and two in 2008. In winter wheat (*cv*. SW Stava), two experiments were established in autumn 2006 and one in autumn 2007. Each crop species was sown in separate experiments at different locations (Table 1). At one experiment with winter wheat, one with oats and four with spring wheat, the previous crops were clover- or grass-clover leys. One experiment with winter wheat and one with oats were preceded by spring cereals. The previous crops in one experiment with oats and one with winter wheat were narrow-leafed lupins and onions, respectively.

The weed flora was dominated by annual weeds at seven sites while perennials dominated one site with oats and two with spring wheat. Both life-forms were dominated by dicotyledonous species.

The organic fertilizer Biofer was applied at a rate of 60–80 kg N ha^{-1} to one experiment with spring wheat and two with winter wheat. One experiment with oats was fertilised with chicken manure applied at 10 tonnes ha^{-1} and one was fertilised with solid cattle manure applied at 20 tonnes ha^{-1}. The remaining four experiments were unfertilised. Eight sites had been organically farmed during 4–15 years and two sites with oats during one year.

Each year, seed from the same lot was used for all experiments with each particular cereal species. The field experiments were conducted by the Field Experimental Divisions at the Rural Economy and Agricultural Society in the respective region.

All spring-sown trials were ploughed in autumn before the start of the experiment and harrowed in spring just before sowing in April or May. The autumn-sown trials were ploughed and harrowed just before sowing in September or October.

At the start of the experiment, 10 soil samples were taken from the 0–20 cm layer, pooled and analysed for soil particle size distribution, soil organic matter content and pH (H_2O).

2.2. Treatments and experimental design

Cereals were sown at row distances of 12.0–12.5 cm (RD_{12}), 24.0–25.0 cm (RD_{24}), 36.0–37.5 cm (RD_{36}) and 48.0–50.0 cm (RD_{48}) (Table 2). With RD_{12}, seed rates normal for the region were used, *i.e.*, 400 germinable seeds m^{-2} for winter wheat, 525 seeds m^{-2} for spring oats and 600 seeds m^{-2} for spring wheat. At wider row distances, seed rates were adjusted so that the distance between individual seeds in the row was either (1) the same as at 12 cm row distance (hereafter referred to as SD_1), or (2) the distance between seeds in the row was reduced to 2/3 the normal ($SD_{2/3}$), or (3) the seed distance in the row was halved ($SD_{1/2}$).

Table 2
Percentage of normal seed rate sown at different row distances (RD) and seed distances within the row (SD) in weed harrowed or inter-row hoed cereals.

Row distance	Weed management	Seed distance		
		SD_1[a] %	$SD_{2/3}$	$SD_{1/2}$
RD_{12}[c]	Weed harrowed	100[b]	–	–
RD_{24}	Inter-row hoed	50	75	100
RD_{36}	Inter-row hoed	33	50	67
RD_{48}	Inter-row hoed	25	38	50

[a] Index denotes seed distance; Normal for the region when seeding at 12–12.5 cm row distance (SD_1), 2/3 of the normal ($SD_{2/3}$), half the normal ($SD_{1/2}$).
[b] Normal seed rates sown at 12–12.5 cm row distance were 400, 525 and 600 germinable seeds m^{-2} in winter wheat, spring oats and spring wheat, respectively.
[c] Index denotes row distance; 12–12.5 cm (RD_{12}), 24–25 cm (RD_{24}), 36–37.5 cm (RD_{36}) and 48–50 cm (RD_{48}).