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Control of perennial weeds in spring cereals through stubble cultivation and mouldboard ploughing during autumn or spring

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ABSTRACT

Creeping perennial weeds are of major concern in organically grown cereals. In the present study, the effects of different timing of mouldboard ploughing with or without a preceding stubble cultivation period, on weeds and spring cereals were studied. The experiments were conducted at two sites in Norway during a two and three-year period, respectively, with the treatments repeated on the same plots. The soil cultivation treatments were a stubble disc-harrowing cultivation period followed by mouldboard ploughing and only mouldboard ploughing. The timing of the treatments were autumn or spring. The density and biomass of the aboveground shoots of *Cirsium arvense* (L.) Scop., *Elymus repens* (L.) Gould, *Sonchus arvensis* L. and *Stachys palustris* L. as well as the total aboveground biomass of the spring cereal crop (oats) were assessed. The control efficiency of *C. arvense* and *S. arvensis* was closely related to timing of the cultivation treatments. Cultivation in spring decreased the population of *C. arvense* and *S. arvensis* compared to autumn cultivation. For *E. repens*, timing of the treatments had no significant effect: the important factor was whether stubble cultivation was carried out (best control) or not. The overall best strategy for controlling the present perennial weed population was stubble cultivation followed by ploughing in spring. However, the associated relative late sowing of the spring cereal crop and lowered crop biomass, were important drawbacks.

1. Introduction

Cirsium arvense (L.) Scop. (Creeping thistle, Canada thistle) and other creeping perennial weeds such as *Elymus repens* (L.) Gould (Common coach-grass) are of major concern in organically grown cereals in the Nordic countries (Salonen et al., 2001) and elsewhere (e.g. Bacher et al., 1997; Cormack, 1999). In conventional farming in Norway, *E. repens* is normally controlled by glyphosate application pre-harvest in ripe barley or post-harvest in (all cereal species) stubble. Broad-leaved species such as *C. arvense* and *Sonchus arvensis* L. (Perennial sow-thistle), on the other hand, are typically controlled by post emergence application of phenoxy herbicides.

In a survey in Finland the total weed biomass in spring cereals was four times higher in organic versus conventional farming. Salonen et al. (2011) claimed that weed management in organic cropping calls for urgent measures such as direct mechanical weed control in crops stands. Although hardly used among farmers in the Finnish study, flex-tine weed harrowing is one the most widely used mechanical methods for control of weed seedlings in organically grown cereals (Armengot et al., 2013). Direct mechanical weed control against perennial weeds (in crop stands), as hoeing, are not so common in the Nordic countries, but provides promising results especially in combination with other cultural methods (Melander et al., 2005). The interest for this measure is growing. Both for preventing huge problems with creeping perennial weeds in organic farming, as well as decreasing the use of herbicides in conventional and integrated farming, there is a need for optimizing the soil tillage operations.

Numerous studies in conventional farming (e.g. Ekeberg et al., 1985; Håkansson et al., 1998) have shown that mouldboard ploughing gives a significant control of perennial weeds. Additionally, there is general agreement that effectiveness increases with the depth of mouldboard ploughing (e.g. Børresen and Njøs, 1994; Håkansson et al., 1998). The main consideration determining the minimum acceptable ploughing depth should be related to weed control, especially of perennials (Kouwenhoven

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et al., 2002). To exemplify the effect of ploughing depth (conducted in spring), shoot numbers of *E. repens* and *S. arvensis*, as well as the total above-ground perennial weed biomass, were around 50% lower with deep (25 cm) compared to shallow (15 cm) ploughing (Brandsæter et al., 2011). The greatest advantage of deep ploughing was the control of *C. arvense*, which in some cases was reduced by more than 90% compared to shallow ploughing. This significant effect of ploughing depth on *C. arvense* may indicate that most shoots arise from the intact root system below the mouldboard plough depth, and not from root fragments. This may again indicate that spring ploughing is more detrimental than autumn ploughing for this species. If the most competitive shoots come from below the ploughing depth and deep ploughing is performed in spring, and the crop is sown shortly after ploughing, spring ploughing may significantly decrease the competitive ability of *C. arvense*.

In the studies of Permin (1961) and Brandsæter et al. (2012) stubble cultivation by shallow ploughing before harrowing in the autumn, gave generally the best control of perennial weeds. In the latter study, however, stubble cultivation by rotary tillage gave similar control as shallow ploughing plus harrowing. Shallow ploughing used for stubble treatment followed by another shallow treatment in late autumn has proven very effective in controlling *C. arvense* (Gruber and Claupein, 2009). Also Melander et al. (2012) concluded that intensive post-harvest cultivation followed by deep inverting tillage control perennial weeds effectively on sandy soils. The efficacy, however, may differ between weed species. Brandsæter et al. (2012) showed generally low effect of stubble treatment in autumn on *S. arvensis* compared to *E. repens*, because *S. arvensis* had probably developed bud dormancy at the time of cultivation (Brandsæter et al., 2010). *S. arvensis* may be better controlled by disturbance, as harrowing and ploughing, in spring because effective depletion is connected to seasons when regrowth is not restricted by physiological dormancy, temperature or drought (Håkansson, 2003). More recently, Ringselle et al. (2016) studied the effect of timing and repetitions of cultivation in autumn on *E. repens*. They concluded that a few days delay in tine cultivation did not reduce the control of *E. repens* compared to such cultivation immediately after crop harvest. A delay by 20 days, however, decreased control efficiency. Furthermore, their study showed that repeated tine cultivation did not improve weed control compared to one cultivation. Although most attention has been given to perennial weeds, stubble cultivation may also decrease annual weed populations (Pekrun and Claupein, 2006).

Very few studies have focused on the effects of timing of stubble cultivation and ploughing on weed growth. Njøs and Ekeberg (1980) found approximately equal effects of ploughing in autumn versus spring on *E. repens*. Agricultural advisers in the Nordic countries claim that spring ploughing gives better control of *C. arvense* and *S. arvensis* than autumn ploughing (Pedersen and Gustavsson, 2003).

Improved weed control from spring tillage will reduce both the need for herbicides in conventional farming and the requirement for mechanical weed control in organic and integrated cropping. Furthermore, methods like hoeing (inter-row cultivation) and frequently mowing of annual green manure lays for weed management may have unwanted effects regarding labour input, land use and energy consumption. For example, the use of green manure crops has under certain circumstances caused N losses, especially in systems that have large amounts of fresh plant material on the surface during winter (Korsæth and Eltun, 2008). Furthermore, spring tillage will give less soil erosion and nutrient leakage from fields than autumn tillage (Ulén et al., 2010). The following arguments against spring ploughing are often given by farmers (who traditionally plough in autumn) (i) ploughing in spring delays sowing as it entails more work at a busy time, (ii) ploughing heavy soils in spring results in a poor seedbed due to greater cloddiness, and (iii) ploughing in spring may hamper capillary rise, which can be a disadvantage under dry conditions.

The present study addresses the following hypotheses: (1) For the control of *C. arvense* the season – autumn vs. spring - of ploughing is more important than whether stubble cultivation is carried out or not, and spring ploughing gives the best control. (2) *S. arvensis* is better controlled by spring- than autumn ploughing, and stubble cultivation in spring will improve the control. (3) For the control of *E. repens*, stubble cultivation prior ploughing is the crucial aspect, while season – autumn vs. spring - of the cultivation is of no significance.

2. Material and methods

2.1. Study sites, experimental design and treatments

The study was located at two sites in SE Norway: (i) the Norwegian University of Life Sciences (NMBU), Ås (59°40′N, 10°46′E, 90 m above sea level) with a sandy loam soil (USDA Soil Survey classification), and (ii) Øsaker, Grålum (59°23′N, 11°02′E, 40 m above sea level) with imperfectly drained clay loam classified as Luvic Stagnosol (Clayic) (World Reference Base, 2006). Prior to the experiments, both fields had been farmed organically for a number of years, mainly with cereal crops.

The trials at Ås and Øsaker were initiated in autumn 2007 and 2008, respectively, and continued until August 2010 at both locations. Trials were designed as randomized block experiments. The four different weed control treatments were built up by two factors (i) soil cultivation and (ii) timing of the cultivation, both with two levels. The soil cultivation levels were (i) a stubble disc-harrowing cultivation period followed by mouldboard ploughing, and (ii) only mouldboard ploughing. Levels of timing of the cultivation was (i) autumn or (ii) spring. Crop was always sown in spring. The four weed control combinations were: stubble cultivation before ploughing in spring (SCPS) or autumn (SCPA) and only ploughing in spring (PS) or autumn (PA). Individual plot size was 5 by 9 m, and each treatment was replicated five (Ås) or four (Øsaker) times. Treatments were repeated on the same plots for 3 years at Ås (autumns 2007–2009 or springs 2008–2010) and 2 years at Øsaker (autumns 2008 and 2009 or springs 2009 and 2010) (Table 1).

The stubble cultivation period consisted of harrowing one pass at 8–10 cm depth, once or twice during autumn or spring, depending on date of cereal harvest (in autumn), weather conditions (Table 2) and whether the perennial weed species reached the growth stage of their compensation point (Håkansson, 2003: *E. repens* 3–4 leaf stage, *C. arvense* 4–7 leaf stage and *S. arvensis* 5-7 leaf stage; Korsmo et al., 2001: *S. palustris* ≈ 6 leaf stage). The compensation point may be defined as the stage where the sink-source dynamics of carbohydrate reserves shifts from the underground organs as the source and aboveground organs as the sink, to the opposite (Håkansson, 2003). Two disc harrow operations in autumn or spring were planned, but this had to be changed to one operation in some cases due to late harvesting and unfavourable weather conditions (Table 1). The harrowing was done when the soil was considered dry enough, by kneading the soil (to 10 cm depth) in the hand and evaluating whether the soil crumbled.

The stubble cultivation was carried out with a Väderstad "Carrier Disc harrow" (http://www.vaderstad.com/en/products/cultivation/carrier_carrierx, accessed 07.03.2017) with working width 5 m at Ås and with a Kverneland Disc harrow with 32 discs with working width 3 m at Øsaker. A Dyna Drive (http://www.bomford-turner.com/cultivation/_product/1/dyna-drive/, accessed 07.03.2017), a ground-driven rotary surface cultivator with working width 3 m, was used to 12–15 cm working depth prior to disc-