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Yield of spring cereals in mixed stands with undersown winter turnip rape

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ABSTRACT

Winter turnip rape [*Brassica rapa* L. ssp. *oleifera* (DC.) Metzg.] is an oilseed crucifer mainly grown in Nordic and Baltic countries. It can be undersown in a spring cereal as an alternative to sowing of pure stand in late July. Establishment by undersowing helps to utilize the short growing season at high latitudes. However, as undersown crops tend to affect the growth and yield of their companion crops, the effect of undersown winter turnip rape on cereal yield and quality needs to be assessed. Additionally, an evaluation of the suitability of different cereals as companion crops to winter turnip rape is required before practical recommendations can be made. The suitability of four spring cereals as companion crops to winter turnip rape was studied in three field experiments. Two-row barley, six-row barley, wheat and oat were sown at two different densities, with and without undersown winter turnip rape, sowing density depending on the density of the cereal. Undersowing winter turnip rape in a cereal did not markedly affect cereal yield. In some years six-row barley and oat with undersown winter turnip rape produced more yield than corresponding pure stands, indicating a possible facilitative effect of the undersown crucifer on the two cereal species. The results suggest that the most compatible cereals as companion crops with undersown winter turnip rape are six-row barley and oat. Mixed stand cultivation could be improved trough the identification of the optimal cereal–winter turnip rape combinations.

1. Introduction

Undersowing winter turnip rape [*Brassica rapa* L. ssp. *oleifera* (DC.) Metzg.] in spring with a cereal represents a practical crop management method that merits investigation (Tuulos et al., 2015a). Because winter turnip rape must be sown by the end of July in Finland, and as the cereals reach maturity usually around August–September, there is no uncultivated land at that point in time (Mäkelä et al., 2011). Hence, undersowing winter turnip rape with a spring cereal in May allows simultaneous cropping of the cereal and the crucifer, which in turn will produce its seed after overwintering (Valle, 1951). Additional benefits of undersowing a crop in a cereal include more efficient use of resources during the growing season (Morris and Garrity, 1993) and capacity to function as an N catch crop after the season (Tuulos et al., 2015b).

Mixed cropping of high-value crops with cereals is not a common practice in northern Europe. However, in the major wheat production areas of China approximately 75% of the wheat area is based on mixed cropping systems (Xu et al., 2013). Establishing overwintering crops, usually leys, by undersowing with a cereal is widespread in northern Europe where the growing season is short and sowing after harvest of the main crop in the autumn could lead to poor development of the crop before overwintering (Alvenäs and Marstorp, 1993). Furthermore, undersowing can improve the growth of slow-developing crops by suppressing weeds during the early part of the growing season (Heddle and Herriot, 1955). Transpiration in mixed stands may increase due to decreased evaporation from shaded soil surface (Morris and Garrity, 1993).

Unfortunately, undersowing has its disadvantages. In order to reduce the competitive effect on the undersown crop, lower cereal seeding density is often required, which in turn reduces the yield potential of the cereal (Känkänen and Eriksson, 2007). Undersown crops also have a tendency to affect growth of the companion crop due to interspecies competition for water, light and nutrients (Silvertown, 1982). In addition, several crops, including crucifers, are known to produce allelochemicals that affect the growth of other species (Kirkegaard and Sarwar, 1998). Some effects of an undersown, non-leguminous crop on the companion cereal crop

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include reduced shoot weight (−23%), height (−9%), and spike (−3%), panicle (−16%) and fertile spikelet (−2%) number, as well as 12% lower grain protein concentration (Charles, 1960). Broadly, a competitive undersown crop will eventually reduce the yield of a cereal by approximately 6–12% (Charles, 1960, 1962; Känkänen and Eriksson, 2007; Picard et al., 2010) leading to a requirement to choose the component crops in mixed stands carefully in order to reduce competition between and within species.

Many studies (Jarvis et al., 1958; Charles, 1960, 1962; Picard et al., 2010) concerning the effect of undersown crops on cereal companion crops incorporate grass and legume species or their mixtures. As legumes release nitrogen into the soil, a cereal could benefit from the undersown legume. The few investigations (Singh et al., 1991; Subedi, 1997; Khan et al., 2005; Wang et al., 2007) on mixtures of crucifers and cereals indicate that the crucifer usually affects the growth and yield of a cereal negatively. Moreover, the magnitude of the effect on the cereal depends on the relative densities of the species and prevailing environmental conditions. However, there are reports (Andersen et al., 2005; Bellostas et al., 2003; Merker et al., 2010) that indicate a beneficial effect of an undersown crucifer on a cereal and therefore predicting the outcome of a cereal–winter turnip rape mixed crop is not easy (Silvertown, 1982). For example, heavy shading decreases wheat yield, whereas moderate shading may promote wheat growth through higher leaf area, higher chlorophyll content or more effective redistribution of assimilates (Li et al., 2010). In addition, different environmental conditions during the growing season can influence the outcome by favoring one species over another (Silvertown, 1982).

In mixed cropping, the radiation use of the individual component species differs from that for corresponding pure stands (Vandermeer, 1989). As neither of the component species can fully utilize the incoming radiation as pure stands, radiation interception can be improved by mixed cropping. The higher number of plants per unit area with their leaves in different layers will lead to increased light interception due to increased leaf area (Vandermeer, 1989). This could increase the net production, at least to the point where the increased leaf area results in higher net respiration of the heavily shaded leaves (Watson, 1958). Even though the proportion of leaf area of each species in a mixed stand cannot be identified when using indirect leaf area measurements, it is still possible to compare the difference in the increase of total leaf area in different cereal–winter turnip rape mixed stands versus pure cereal stands.

The objective of this work was to investigate the effect of undersown winter turnip rape and its seeding density in four different spring cereals by analyzing the cereal densities and the cereal grain yield and its quality. A further objective was to establish whether mixed cropping of cereals and winter turnip rape affects the growth of the individual species and whether that manifests as differences in leaf area index.

2. Materials and methods

2.1. Plant material and experimental design

Three field experiments were conducted during 2008–2011 at the Viikki Experimental Farm (60°13′N, 25°02′E, 8 m above sea level), University of Helsinki, Finland, as described in Tuulos et al. (2015a). The soil was silty clay loam (silt 30–40%, clay 50–60%, sand 10–20%) with organic matter content of 3.0–5.9% and pH 6.1. According to the WRB system (IUSS Working Group WRB, 2006) the soils were typically Luvic Gleysols and Luvic Stagnosols. Plant material consisted of oat (*Avena sativa* L.) 'Marika', wheat (*Triticum aestivum* L. emend. Thell.) 'Zebra', two-row barley (*Hordeum vulgare* L.) 'Xanadu', six-row barley 'Vilde', and winter turnip rape 'Largo'. The experiments were conducted in a randomized complete block designs with four replicates. The combinations of different cereals and seeding densities (Table 1) with winter turnip rape were randomly assigned to plots of 10 m^2 (8 × 1.25 m). For cereal pure stands and mixed stands with high winter turnip rape density (300 viable seeds/m^2), normal commercial sowing density was used (two-row barley and wheat: 600 seeds/m^2, six-row barley and oat: 500 seeds/m^2). For mixed stands with normal commercial winter turnip rape density (150 viable seeds/m^2), a reduced (−20%) cereal sowing density (two-row barley and wheat: 480 seeds/m^2, six-row barley and oat: 400 seeds/m^2) was used in 2009 and 2010.

Cereal seeds were dressed with 1.5 g/kg seed of Baytan I (triadimenol 150 g/kg and imazalil 25 g/kg; Bayer CropScience) and turnip rape seeds in 2008 with 25 ml/kg seed of Cruiser OSR (thiamethoxam 280 g/l, metalaxyl-m 32.3 g/l, fludioxonil 8 g/l; Syngenta) and in 2009 and 2010 with 18.75 ml/kg seed of Elado FS480 (chlothianidin 400 g/l and betacyfluthrin 80 g/l; Bayer CropScience). Cereal plots were sown on 13 May 2008, 5 May 2009 and 15 May 2010, and the undersown turnip rape on the same day with a plot drill (Wintersteiger TC2700, Wintersteiger AG, Ried, Austria). Fertilizer (80 kg/ha N, N-P-K: 20-2-12; Pellon Y4, Yara) was applied to the seedbed at the time of sowing. Row spacing was 12.5 cm and rows of different species in mixed stands were sown parallel to each other. Cereals were sown in all plots at a depth of 50 mm and winter turnip rape at 20 mm below the soil surface, after which the plots were rolled (Tuulos et al., 2015a).

Insect pests were controlled in 2009 with 0.6 l/ha Bioruiskute S (pyrethrins 100 g/l; Yara) and 0.5 l/ha Roxion (dimethoate 400 g/l;

Table 1
Combinations of cereals and winter turnip rape at different densities used in experiments in 2008–2010. Seeding density of a sparse winter turnip rape stand was 150 seeds/m^2 and a dense stand 300 seeds/m^2.

Cereal species	Stand type	Cereal density (seeds/m^2)	
		2008	2009 and 2010
Two-row barley	Pure	550	600
	Mixed with sparse winter turnip rape	550	480
	Mixed with dense winter turnip rape	550	600
Six-row barley	Pure	500	500
	Mixed with sparse winter turnip rape	500	400
	Mixed with dense winter turnip rape	500	500
Wheat	Pure	650	600
	Mixed with sparse winter turnip rape	650	480
	Mixed with dense winter turnip rape	650	600
Oat	Pure	500	500
	Mixed with sparse winter turnip rape	500	400
	Mixed with dense winter turnip rape	500	500