Competition of some summer catch crops and volunteer cereals in the areas with limited precipitation

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ABSTRACT

Competitive ability of six summer catch crops (*Brassica napus*, *Lolium multiflorum*, *Lolium perenne*, *Phacelia tanacetifolia, Sinapis alba* and *Trifolium incarnatum*) in volunteer winter wheat based on field trials was experimentally tested during the years 2004–2007 in central Bohemia (Czech Republic). The production of aboveground biomass and plant cover of sown catch crops, volunteers and weeds was assessed on experimental plots. General linear models revealed significant influence of catch crops, year and their interaction on dry-mass of the volunteers. The lowest average values of volunteer biomass at the end of growing season (average from 2004–2007) were recorded on plots sown with *S. alba* (124.7 kg/ha) and *P. tanacetifolia* (186.3 kg/ha). The average biomass of volunteer plants in stands of *S. alba* was significantly lower than the biomass of volunteers in stands of *L. perenne*, *L. multiflorum* and *T. incarnatum*. The lowest average biomass of weeds was recorded also in *S. alba* stands. In the context of our study, catch crop is a crop sown between seasons of regular plantings to make use of temporary idleness of the soil.

Keywords: summer catch crops; volunteer cereal; biomass production; plant cover

Growing of catch crops has many benefits to farmers. In the context of our study, catch crop is a crop sown between seasons of regular plantings to make use of temporary idleness of the soil. It improves soil quality, eliminates erosion, decreases nutrient losses, lowers infection pressure of diseases and pests, and improves weed management (Liebman and Dyck 1993, Lewan 1994, Poggio 2005). The development of summer catch crop stands and their biomass production relies, however, particularly on the amount of precipitation, availability of soil water, and on sowing date (Gregorová 1992, Lütke Entrup and Oehmichen 2000, Brant et al. 2005). Especially dense stands of summer catch crops with high competitive ability show high coverage of the soil and high biomass production; they are able to ensure soil conservation and weed suppression. Freyer (2003) presents that good ability to suppress weeds can be found in the stands of *Sinapis alba*, *Raphanus sativus* var. *oleiformis*, *Trifolium alexandrinum*, and *Trifolium resupinatum,* and lower in stands of *Phacelia tanacetifolia* and *Fagopyrum esculentum*. According to Brant et al. (2006a), *Sinapis alba* and *Phacelia tanacetifolia* stands showed high soil coverage when grown as summer catch crops in dry regions.

Catch crop stands are not negatively influenced only by typical weed species – their development is strongly influenced by volunteer plants of previous crop. The occurrence of volunteers in catch crops is considered as undesirable because of the competition with sown catch crop and occurrence of pests and diseases (Hoffmann and Schmutterer 1999, Limpert et al. 1999). On the other hand, volunteers have an important role in the stand's total biomass production, soil radiation fixation, nutrient sorption, elimination of soil erosion, etc. Beaudoin et al. (2005) showed that the dry biomass production of volunteer *Pisum sativum*, *Hordeum vulgare*, and *Brassica napus* in their experiments was 0.9 t/ha and the volunteer occurrence on the

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stands increased biological fixation of nitrogen. Under the conditions of central Europe, summer catch crops are mostly sown after cereal crops. Volunteer cereals germinate and emerge well after stubble tillage and compete significantly with sown catch crop. Garbe and Heitefuss (1988) found that the stands of *Sinapis alba* reaching the height of 0.68 m and more can compete very successfully with the volunteer barley. When the height of the stand was between 0.35–0.45 m, the reduction of volunteers was not recorded. The development of previous volunteer cereal crop is also influenced by the stubble tillage used (Freyer 2003). Shallow tillage can lead to increased occurrence of volunteers in the stands of catch crops. Higher frequency of volunteers was found by Pekrun and Claupein (2001) in the variants with rotary tiller than in those where the cultivator and/or plough was used.

The aim of this work was to evaluate the competitiveness of catch crops against volunteers in areas of low precipitation based on elevation of the dynamics of the production of aboveground biomass of the sown catch crops and production of the previous grain crop volunteers. Simultaneously, it concerned a quantification of the production of the aboveground biomass of volunteers as a source of organic matter in the agricultural system, between the regular crop seasons.

MATERIAL AND METHODS

Field experiments were carried out in 2004–2007 in central Bohemia at the experimental station of Červený Újezd (398 m above sea level) with an average yearly temperature of 7.9°C and yearly precipitation of 525.8 mm (geographical coordinates: 50°04'34.45''N, 14°09'22.351''E – WGS 84). The soil can be classified as clay loam. According to the latest climatic regionalization of the Czech Republic (Moravec and Votýpka 2003) the locality falls into Class III, which is characterized by an average duration of the main vegetation period within the range of 160–177 days, the average annual totals of precipitation below 580 mm and the rainless period of more than 22 days. Table 1 shows monthly totals of precipitation, potential evapotranspiration and monthly average of air temperature at the experimental location, from May to October in the years 2004–2007.

Precipitation totals (P, mm, accuracy 0.1 mm per tip) were collected by a tipping bucket rain gauge RS03 (Fiedler, CZ) within a 1 h interval, air temperature (t, °C) was measured by datalogger Minikin TH (EMS Brno, CZ) every 10 min. Potential evapotranspiration values (PET, mm) were calculated by the Turc algorithm (Turc 1961). Values of the meteorological phenomena in the same period relating to the catch crop development are documented in Table 2.

Following species were planted as summer catch crops on experimental plots: *Brassica napus* L. (cv. Bristol), *Lolium multiflorum* Lamk. (cv. Prolog), *Lolium perenne* L. (cv. Lonar), *Phacelia tanacetifolia* Bentham (cv. Větrovská), *Sinapis alba* L. (cv. Veronika) und *Trifolium incarnatum* L. (cv. Kardinál). The experiments were established in four replicates for each catch crop variant in randomised design and repeated from

Table 1. Monthly totals of precipitation (P), potential evapotranspiration (PET) and monthly average of air temperature (t) from May to October in the years 2004–2007 and long-term climatological normals for the period 1961–1990 of precipitation (P) and monthly average of air temperature (t) for meteorological station Prague-Ruzyně

Month	2004			2005			2006			2007			Normal*	
	P (mm)	PET (mm)	t (°C)	P (mm)	PET (mm)	t (°C)	P (mm)	PET (mm)	t (°C)	P (mm)	PET (mm)	t (°C)	P (mm)	t (°C)
V.	64.1	74.6	11.4	91.5	83.0	13.5	90.0	89.8	13.3	58.7	99.3	14.6	38.2	7.7
VI.	95.4	90.7	15.3	77.3	94.6	16.3	58.3	113.2	16.8	71.9	111.3	18.0	77.2	12.7
VII.	49.0	100.4	17.3	141.4	101.5	18.1	27.0	137.2	21.8	94.1	109	18.5	72.7	15.9
VIII.	58.5	96.2	18.7	70.6	82.0	16.2	98.7	73.7	15.7	99.8	95.8	18.0	66.2	17.5
IX.	40.0	66.8	13.8	24.2	64.8	14.6	5.4	73.6	16.4	73.2	47.7	12.3	69.6	17.0
X.	30.4	32.7	9.4	14.2	35.2	9.5	29.9	35.4	10.6	23.1	26.4	7.8	40.0	13.3

*source – Czech Hydrometeorological Institute

Table 2. Totals of precipitation (P) in the assessed periods in the years 2004–2007

2004		2005		2006		2007	
period	P (mm)	period	P (mm)	period	P (mm)	period	P (mm)
1.5.–12.8.	212.6	1.5.–23.8.	380.2	1.5.–29.8.	272.9	1.5.–13.8.	291.2
13.8.–30.9.	94.4	24.8.–13.9.	6.3	30.8.–25.9.	6.3	14.8.–9.9.	51.9
1.10.–25.10.	26.6	14.9.–3.10.	28.3	26.9.–10.10.	18.6	10.9.–2.10.	55.6
26.10.–7.11.	11.4	4.10.–19.10.	1.6	11.10.–31.10.	11.5	3.10.–31.10.	22.1
13.8.–2.11.	132.4	24.8.–19.10.	36.2	30.8.–31.10.	36.4	14.8.–31.10.	129.6
1.5.–7.11.	345.0	1.5.–19.10.	416.4	1.5.–31.10.	309.3	1.5.–31.10.	420.8

2004 to 2007. The area of each experimental plot was 30 m^2 (3 × 10 m). The catch crop sowing followed the *Triticum aestivum* L. (cv. Alana, winter wheat) harvest. Straw was crushed and distributed over the field during harvest. Harvesting dates were August 9th 2004, August 19th 2005, August 24th 2006 and August 13th 2007. In 2004, stubble ploughing was carried out to a depth of 0.12 m because of the very dry soil. In 2005–2007, the field was prepared by a rotary tiller to a depth of 0.08 m because of high soil moisture. Catch crops were sown immediately after stubble ploughing (August 13th 2004, August 24th 2005, August 30th 2006 and August 14th 2007). This was followed by harrowing of the field plots. The catch crops sowing rates are shown in Table 3. Dry aboveground biomass (kg/ha) of catch crops, cereal volunteers and weeds were assessed on October 1st, October 26th, and November 8th in 2004; on September 14th, October 4th, and October 20th in 2005; on September 26th, October 11th, and November 1st in 2006 and on September 10th, October 3rd, and November 1st in 2007. The degree of coverage of stands (%) was assessed on November 8 th 2004, October 20th 2005, November 1st 2006, and November 1st 2007 only. Within each experimental plot two subsamples of 0.1 m^2 were randomly selected, plants were cut near the surface, and biomass was separated into catch crop, cereals volunteers and weeds. All samples were weighed after oven drying at 85°C for 48 h. Cover was determined by a random method using frames of 0.25 m^2 in two subsamples on each experimental plot (Brant et al. 2006a).

Differences in dry mass of volunteers over season were tested by repeated measures ANOVA with experimental plot as subject variable and sampling date as within-subject factor. Tests were separately performed for each catch crop and year, respectively. The regression analysis was used for the evaluation of competitive ability of catch crops stands over volunteers. General linear model was performed on the dry mass of volunteers in the last sampling date with year and catch crop as fixed factors. *Post-hoc* multiple comparison tests were conducted by means of the Tukey test. Statistical analyses were carried out in the STATGRAPHICS®Plus 4.0 and NCSS 2001 software (Hintze 2001).

RESULTS AND DISCUSSION

Based on meteorological characteristics (Table 2) it is evident that individual years differed especially from the point of view of soil moisture conditions. In 2004, there was precipitation of 132.4 mm from the sowing date of catch crops till the date of last biomass sampling. In 2005 and 2006, the sum of precipitation during the same period was only 36.2 mm and 36.4 mm, respectively. Compared to the year 2004, the years 2005 and 2006 were very rich in precipitation in the period between 1st May and 31th October (Table 1). The year 2007 differed considerably from the previous years, as this year was rich in precipitation not only till the sowing date of catch crops, but also after this date.

In 2004, the lowest values of aboveground biomass of the volunteers were found by the end of growing

Table 3. Cover crops sowing rates in 2004–2007

Catch crops	Seeding rate (kg/ha)
Brassica napus	10
Lolium multiflorum	40
Lolium perenne	20
Phacelia tanacetifolia	10
Sinapis alba	20
Trifolium incarnatum	25

Table 4. Dry matter production (kg/ha) of volunteers in the years 2004–2007

Date	Dry matter production of volunteers in the stands of catch crops (kg/ha)					
	Brassica napus	*Lolium multiflorum*	*Lolium perenne*	*Phacelia tanacetifolia*	*Sinapis alba*	*Trifolium incarnatum*
1.10. 2004	25.1[a]	20.6[a]	23.1[a]	22.0[a]	20.5[a]	20.7[a]
26.10. 2004	145.8[b]	38.6[a]	63.8[a]	42.1[a]	37.3[ab]	60.3[ab]
8.11. 2004	158.5[b]	49.4[a]	65.9[a]	68.1[a]	67.3[b]	137.9[b]
14.9. 2005	148.3[a]	146.7[a]	197.8[a]	232.5[a]	146.1[a]	209.5[a]
4.10. 2005	490.6[b]	537.6[b]	499.5[b]	658.9[b]	330.3[a]	447.1[ab]
20.10. 2005	586.4[b]	541.4[b]	673.9[c]	402.3[a]	254.0[a]	533.6[b]
26.9. 2006	133.5[a]	199.0[a]	134.8[a]	99.0[a]	119.3[a]	100.4[a]
11.10. 2006	252.5[a]	395.8[b]	471.3[b]	269.0[b]	95.5[a]	253.0[ab]
1.11. 2006	316.3[a]	191.0[a]	364.8[b]	146.5[a]	99.1[a]	349.1[b]
10.9. 2007	106.4[a]	133.1[a]	136.8[a]	110.6[a]	114.0[a]	88.0[a]
3.10. 2007	231.1[a]	435.9[ab]	167.4[a]	242.6[b]	92.8[a]	368.3[ab]
1.11. 2007	165.6[a]	708.6[b]	1075.8[b]	128.4[ab]	78.5[a]	527.0[b]

ANOVA; α = 0.05; different letters document statistically different means columnwise, each year is tested separately

season (November 8th 2004) in stands of *L. multiflorum* (49.4 kg/ha) – Table 4. For the stands of this variant high cover (39.1%) was typical. The highest values of aboveground biomass of volunteers were found in stands of *B. napus* (158.5 kg/ha).

Stands of all catch crops tested showed a high degree of volunteer weediness in the year 2005. In 2005, aboveground biomass of volunteers was higher than in 2004 (Table 4). In 2005, at the end of growing season, the lowest values of volunteer aboveground biomass were found in the stands of *S. alba* (254.0 kg/ha) and *P. tanacetifolia* (402.3 kg/ha). Volunteer biomass in stands of *S. alba* and *P. tanacetifolia* at the end of growing season (October 20th 2005) was lower compared to that found during previous sampling (Table 4). Especially the stands of *S. alba* produced high amount of aboveground biomass (1799.1 kg/ha) – Figure 1. In 2005, the highest volunteer weediness was found in stands of *L. perenne* and *B. napus* (Table 4).

Occurrence of volunteers in evaluated stands in 2006 was similar to 2005. The lowest biomass of volunteer forecrop at the end of growing season was found in stands of *S. alba* (99.1 kg/ha) and *P. tanacetifolia* (146.5 kg/ha). These stands exhibited high aboveground biomass of catch crops (Figure 1).

In 2007, the lowest values of volunteer aboveground biomass production were also found in stands of *S. alba* and the highest ones in stands of *L. perenne* (Table 4).

The lowest average values of volunteer biomass at the end of growing season (2004–2007) were found on plots sown by *S. alba* and *P. tanacetifolia* (Table 5). The average volunteer biomass production in stands of *S. alba* was significantly lower compared to that in stands of *L. perenne*, *L. multiflorum,* and *T. incarnatum*. The lowest biomass of weeds was recorded in the stands of *S. alba* as well (Table 5). The highest average production of aboveground biomass of catch crop was found in stands of *S. alba* (Table 5). The stands of *S. alba* showed also the highest average plant cover of all sown species (Table 5). The lowest average values of coverage of volunteers and weeds were recorded in stands of *S. alba* and *P. tanacetifolia* (Table 5). It is evident from Figure 2 that increasing biomass of the crop leads to the decrease of biomass production of volunteer plants.

Figure 3 documents the influence of the year and sown catch crop species onto the aboveground biomass dynamics of volunteers at the end of growing season. General linear models revealed a significant influence of catch crop ($F_{5,140}$ = 18.99, P < 0.001), year ($F_{3,28}$ = 26.97, P < 0.001) and their interaction ($F_{15,140}$ = 7.18, P < 0.001) on dry matter of volunteers (Figure 3). Therefore, the ability of respective catch crops to suppress development of volunteers differed from each other and from one year to the next. In 2004, no significant differences were found in dry matter of volunteers with respect to different catch crops and the dry

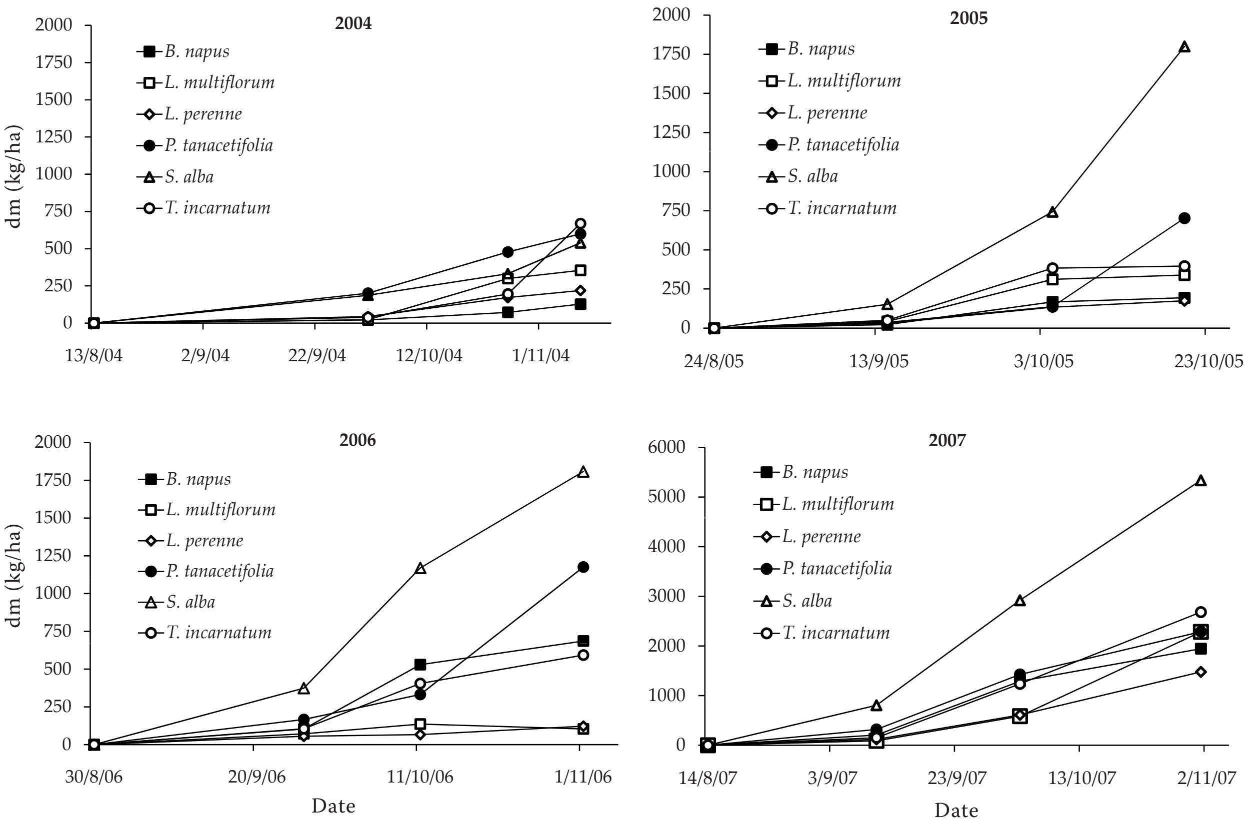

Figure 1. Dynamics of aboveground dry matter production (dm, kg/ha) of catch crops in the years 2004–2007. First day is the day of catch crop sowing

matter production of volunteers was generally very low. In 2005, big differences in dry matter production of volunteers with respect to catch crops were found. Except for *P. tanacetifolia*, stands with *S. alba* showed a significantly lower dry production of volunteers than stands of other catch crops. In 2006, dry matter production of volunteers showed trends similar to those observed in 2005; moreover, stands of *S. alba* suppressed the development of volunteers most successfully that year. Strong differences in dry matter production of volunteers were found among stands with different catch crops in 2007. While stands with *S.alba*, *P. tanacetifolia* and *B. napus* strongly suppressed the development of volunteers, stands with *T. incarnatum*, *L. multiflorum*, and especially with *L. perenne* had only medium or low influence on the dry matter production of volunteers.

Year-to-year variation in the dry matter production of volunteers among the stands with

Table 5. Dry matter production (kg/ha) and plant cover (%) of cover crops, volunteers and weeds (average 2004–2007)

Catch crop	Dry matter production (kg/ha)			Plant cover (%)		
	catch crop	volunteer	weeds	catch crop	volunteer	weeds
Brassica napus	738.1^{a}	306.7^{ab}	68.0^{a}	25.0^{a}	15.4^{b}	5.6^{bc}
Lolium multiflorum	769.9^{a}	372.6^{bc}	61.8^{a}	32.6^{ab}	13.1^{ab}	5.2^{bc}
Lolium perenne	498.3^{a}	544.5^{c}	80.7^{a}	20.9^{a}	12.4^{ab}	6.7^{c}
Phacelia tanacetifolia	1191.0^{a}	186.3^{ab}	64.6^{a}	49.8^{c}	8.8^{a}	3.5^{ab}
Sinapis alba	2370.6^{b}	124.7^{a}	51.6^{a}	55.9^{c}	8.4^{a}	2.8^{a}
Trifolium incarnatum	1085.0^{a}	386.9^{bc}	68.5^{a}	45.7^{bc}	16.7^{b}	5.9^{c}

ANOVA; $\alpha = 0.05$; different letters document statistically different means columnwise

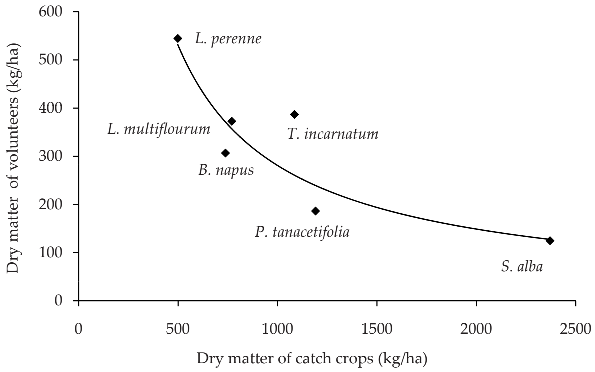

Figure 2. Relationship between the dry matter production of catch crops (dm, kg/ha, y) and the dry matter production of volunteers (dm, kg/ha) at the end of vegetation (Regression analysis – multiplicative model, average values were used for individual crops in the period 2004–2007). The equation of the fitted model is: $y = 157244.0x^{-0.916015}$, $R^2 = 82.26\%$

catch crops tested were lower for the stands with *T. incarnatum* ($CV = 48.3\%$), *B. napus* (65.3%), and *S. alba* (69.9%) than for stands with *P. tanacetifolia* (79.3%), *L. perenne* (79.5%), and *L. multiflorum* (81.8%).

Based on experimental results it is obvious that the biomass production of volunteer cereals in catch crops stands is influenced mostly by catch crop species and its aboveground biomass production (Figure 2). The experimental year plays an important role as well (Figure 3), especially the moisture conditions during the season. Another important factor is the method used for stubble tillage.

Low precipitation before sowing of catch crops in 2004 negatively influenced the moisture conditions of the soil and consequently also catch crops stands development (Table 2). The precipitation in the period from August 13th 2004 till September 30th 2004 positively influenced seed germination and emergence on the stands but did not provide sufficient water supply for canopies in the following period. Water deficiency led to development of catch crops canopies with weak competitive ability. This deficiency probably also influenced the development of volunteer plants – their biomass production was lower compared to other years (2005–2007). Lower biomass of volunteers in catch crop stands could be also explained by the soil tillage system used. As a result of stubble ploughing, the cereal caryopses were incorporated into the deeper soil layers, which negatively influenced their germination and subsequently seedling emergence. Pekrun and Claupein (2001) showed that deeper cultivation of the soil during stubble tillage leads to the reduction of cereal volunteers.

In 2005 and 2006, good water reserve in soil was set up before catch crops sowing. This influenced not only catch crops emergence but also following development of the stands (Table 2). Even though the sum of precipitation from the date of sowing till the last sampling was lower during these years compared to the year 2004 (Table 2), good water storage in the soil led to the development of dense canopies of catch crops; it resulted from the space arrangement of the soil matter on experimental plots ensuring good water supply from deeper soil layers to upper ones (Brant et al. 2006b). Sufficient moisture conditions influenced positively also the development of volunteers; it was supported not only by accessible water in the soil, but also by shallow soil tillage which allowed caryopses to be stored in upper soil layer. The development of volunteer plants however negatively influenced the growth of catch crops stands. Especially catch crop species with slow development (*T. incarnatum* and *Lolium* sp.) and those with weak competitive ability (*B. napus*) were strongly affected by volunteers. Lower competition of *B. napus* plants is related to worse emergence of canopies, which is caused by the sensitivity of *B. napus* to worse seedbed preparation. Stubble breaking is connected with the creation of larger soil aggregates that lead to larger pores in the soil. These circumstances influenced negatively germination and seedling emergence of *B. napus*. Because of their slower growth, *Lolium* sp. have a weak competitive ability against the well-emerging and rapidly growing volunteers. The reduction of volunteer biomass at the end of growing season in 2006 compared to that in previous sampling was caused by water deficiency at the end of season and also by intraspecific competition of volunteer plants (Table 4). These factors probably also influenced the lower values of volunteer biomass in 2006 compared to the years 2005 and 2007 (Figure 3).

Good competitive ability against volunteers was observed especially in stands of *S. alba* and *P. tanacetifolia*. When a sufficient precipitation occurs, these crops can rapidly overgrow volunteer plants and shade them as a result of high canopy coverage. Garbe and Heitefuss (1988) described a positive

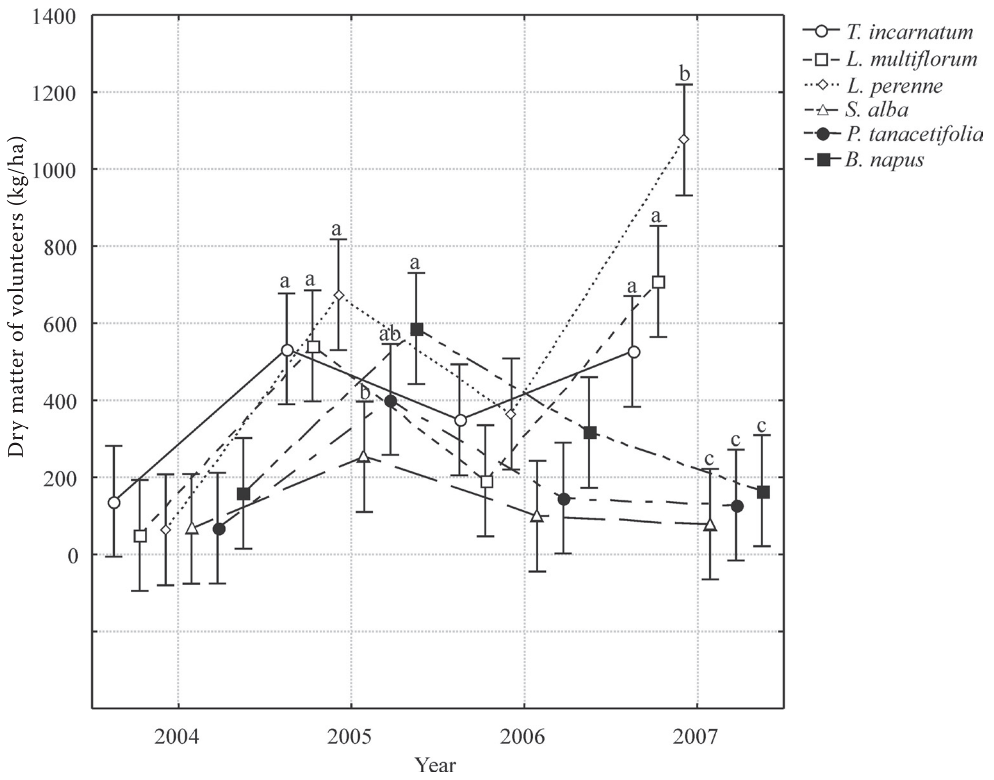

Figure 3. Least-square means (±95% CI) of dry matter production of volunteers (dm, kg/ha) under different cover crops over four years. Significantly different means within each year are labelled by different letters (Tukey test, α = 0.05). In 2004 and 2006, no significant differences were found in dry-mass of volunteers among different cover crops

influence of *S. alba* canopies onto the reduction of cereal volunteers. *S. alba* ability to suppress cereal volunteers increased with the height of the canopy. Another reason of volunteer reduction – especially in *S. alba* stands – is deeper rooting in the soil compared to volunteer plants, which can decrease the water availability for shallowly rooting volunteers. Biomass production of *S. alba* stands and their coverage depends on sufficient water supply. Water deficiency can promote change to earlier flowering of *S. alba* plants. Flowering phase is related to the end of plant growth and to the production of both aboveground and underground biomass production. Consequently, plants enter the senescence period, which leads to withering of leaves and fallout and, subsequently, to the decrease of canopy cover. The decrease of cover leads to a decrease of canopy competitive ability; when followed by higher precipitation activity together with warmer temperatures at the end of growing period, the canopies become weedy. This situation was recorded on experimental plots in 2006 as a result of low precipitation in September and higher precipitation in October. Stands of *P. tanacetifolia* reduced volunteers less effectively than those of *S. alba* – mostly because of their slower development and also due to plant habit resulting in lower soil coverage.

In terms of achieving the aims of catch crops growing, particular year with its actual weather conditions at the time is one of the most important factors. Weather conditions do not influence only the biomass production of catch crops, but also of volunteers, that are competitively stronger compared to lower catch crop species, especially during the years that are rich in precipitation.

It is important for the successful catch crop growing to reduce volunteer plants in the field. Especially the catch crop species with slow development and lower aboveground biomass production can be seriously harmed by volunteers. High harvest losses and shallow soil tillage lead to intensive volunteer occurrence on the stands. During wet years and when early harvest of cereals is used, it is more effective to do the stubble tillage and subsequent catch crop sowing after volunteer emergence. Increased occurrence of volunteers in catch crops stands can lead to the decrease of biomass production and coverage of catch crops stands, to the decrease of their positive phytosanitary influence, and finally to the failure of the aims of catch crops growing in the farming system.

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