Agronomy Research **17**(X), xxx–ccc, 2019
https://doi.org/10.15159/AR.19.164

The effect of sowing date on cover crop biomass and nitrogen accumulation

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Abstract. Cover crops are important tools for reducing nitrogen (N) leaching from the soil and improving the nutrition of cash crops. In northern regions with short autumns it is important to maximise the growing season of cover crops to achieve sufficient biomass and N accumulation. The objective of the study was to evaluate the biomass and N accumulation of cover crops at different sowing dates in August.
Field experiment at Estonian Crop Research Institute was conducted in 2017 and 2018 with white mustard (*Sinapis alba* L.), phacelia (*Phacelia tanacetifolia* Benth), buckwheat (*Fagopyrum esculentum* Moench), berseem clover (*Trifolium alexandrinum* L.), field pea (*Pisum sativum* L.) and faba bean (*Vicia faba* L.). Cover crops were sown on August 3, 8, 14 and 18 in 2017 and August 3, 8, 13, 17 and 23 in 2018.
The two year experiment showed that biomass and N accumulation of cover crops were reduced with delayed sowings, but the reduction mainly depended on cover crop species.
White mustard, field pea and faba bean accumulated significantly higher amount of biomass and N than phacelia, buckwheat and berseem clover at all sowing dates in both years. Because of a rapid decrease in biomass, the optimum sowing time for phacelia and buckwheat should not be later than middle of August. In both year berseem clover produced the modest amount of biomass and therefore more suited as spring sown cover crop in Estonian conditions.

Key words: biomass, cover crops, nitrogen accumulation, sowing date.

INTRODUCTION

Cover crops can reduce N losses from the soil and improve the nutrition of cash crops (Thorup-Kristensen et al., 2003; Arlauskiene & Maikšteniene, 2008; Sapkota et al., 2012; Munkholm & Hansen, 2012). They provide many other valuable ecosystem services such as to build soil organic matter, and to support beneficial soil organisms. They can also inhibit weeds, pests, and diseases, as well as improve soil and water quality (Snapp et al., 2005; Kaspar & Singer, 2011).

The commonly used cover crop species were selected in the study. White mustard (*Sinapis alba* L.), phacelia (*Phacelia tanacetifolia* Benth.) and buckwheat (*Fagopyrum esculentum* Moench) were chosen because of their rapid emergence and growth in the fall, and their effectiveness of taking up residual nutrients from the soil (Talgre et al., 2011; Björkman et al., 2013; Brust et al., 2014). Legumes field pea (*Pisum sativum* L), faba bean (*Vicia faba* L.) and berseem clover (*Trifolium alexandrinum* L.) were selected because of biological nitrogen fixation ability (Talgre et al., 2011; Clark, 2012).

The nitrogen accumulation of cover crop is largely dependent on the amount of biomass they can produce by the termination time. Early planting is major factor that influences cover crop biomass yield (Etemadi et al., 2018). However, the unfavourable weather conditions often cause later harvest of cash crop and therefore delay establishment of cover crops.

Previous research has shown that the cover crop biomass and nitrogen accumulation decreased with delayed sowing. Studies in northeast United States showed that two weeks of planting delay caused 55–62% reduction of faba bean biomass (Etemadi et al., 2018). Zaniewicz-Bajkowska et al. (2013) reported about 45% biomass reduction of phacelia, amaranth, sunflower, seradella and faba bean after four weeks planting delay in Poland.

In Estonia white mustard, phacelia, faba bean and field pea have shown to be great biomass producers in the beginning of August (Talgre et al., 2011). However, the studies with delayed sowing of cover crops have not been previously investigated. Therefore the experiment was conducted to evaluate the biomass and nitrogen accumulation of these species and new potential species (buckwheat and berseem clover) at different sowing dates.

MATERIALS AND METHODS

Field experiments were established in 2017 and 2018 at Estonian Crop Research Institute (58° 44′ 59.41″ N, 26°24′ 54.02″ E) at a climate zone with an average annual temperature of 5.3 °C and precipitation of 670 mm (Estonian weather service). The soil type in the experimental area was Cambic Phaeozem (Loamic) soil (IUSS 2015). The soil characteristics were as follows: pH_{KCl} 6.9, P 104 mg kg^{-1}, K 195 mg kg^{-1}, Ca 3,700 mg kg^{-1}, Mg 510 mg kg^{-1}, C_{org} 2.1% and N_{tot} 0.16%. The following cover crop species were used in the study (seeding rate in brackets): white mustard cultivar (cv.) 'Braco' (18 kg ha^{-1}), phacelia cv. 'Stala' (12 kg ha^{-1}), buckwheat cv. 'Aiwa' (70 kg ha^{-1}), berseem clover cv. 'Akenaton' (15 kg ha^{-1}), field pea cv. 'Kirke' (280 kg ha^{-1}) and faba bean cv. 'Kontu' (280 kg ha^{-1}). Cover crops were sown on August 3, 8, 14 and 18 in 2017 and August 3, 8, 13, 17 and 23 in 2018, after harvest of winter wheat (*Triticum aestivum* L.). The soil was disc harrowed before cover crop sowing. Plots with an area of 4 x 6 m were arranged in a randomized complete block design with four replications. The above and below ground biomass samples were collected from four randomly placed squares of 0.25 m^2 in each plot at the end of vegetation period (20th and 23th of October in 2017 and 2018, respectively), before ploughing the cover crops into the soil. Above ground biomass was cut on the ground level. Roots were taken with a shovel to a depth of 25 cm and washed from soil on a sieve with a mesh size 0.5 mm.

The samples were oven-dried at 65 °C to a constant weight for dry matter (DM) determination and milled for elemental analysis. Plant total N concentrations were determined in Soil Science and Agrochemistry laboratory at Estonian University of Life Sciences by the Dumas Combustion method on a varioMAX CNS elemental analyser (‘Elementar’, Germany).

Precipitation and air temperature were measured daily at a meteorological station located near the field trial site. In 2017 the average air temperature was moderately higher than the long-term average in August by 0.6 °C, and in September by 1.2 °C. Rainfall in August (83 mm) was similar to the long-term average (89 mm), but it was considerably higher in September (86 mm) and October compared to the long term average (66 mm) (Table 1).

The weather conditions in 2018 autumn were not favourable for cover crop establishment. Average air temperature in July was 20.3 °C, which is 3.4 °C higher than the long term average. The soil conditions were very dry as the amount of precipitation was only 15 mm. The average air temperature in August was 2.4 °C higher than the long term average. The rainfall started from 4th of August, but the amount of precipitation in August was still 22 mm lower than the long term average. The average temperature in September was even 4.1 °C higher than the long term average. Rainfall (72 mm) was similar to the long-term average (66 mm), but occurred mostly at the end of the month (Table 1). The first night frost occurred at 29th of September in both years. The plant vegetation period ended at 20th and 23th of October in 2017 and 2018, respectively.

Statistical analyses were carried out by statistical package Agrobase 20^{TM}. To test the differences of biomass and nitrogen (N) accumulation of cover crops, the 3-factor ANOVA (cover crop, sowing date, year and their interaction) was used. In case of significant factors Fisher's LSD test was performed.

Table 1. Average air temperature and precipitation per ten-day period and monthly sums of effective air temperatures > +5 °C (ETS) during the experimental period

Long-term average	Air temperature per 10 day period			Long-term average 1922–2017) (per month)	Rainfall			Long-term average 1922–2017) (per month)	ETS	Long-term average 1922–2017) (per month)
	1	2	3		1	2	3			
2017										
July	13.8	14.8	16.1	16.8	8	45	4	79	308	365
August	17.3	17.5	13.1	15.3	22	35	26	89	337	320
September	12.4	12.5	10.5	10.6	14	71	1	66	206	177
October	7.4	7.1	0.3	5.3	54	38	15	66	53	60
2018										
July	15.6	21.7	23.2	16.8	10	5	0.5	79	474	365
August	21.1	17.3	15.6	15.3	31	29	16	89	401	320
September	17.2	14.1	9.5	10.6	1	26	45	66	260	177
October	7.9	9.3	2.7	5.3	33	1	43	66	86	60

RESULTS AND DISCUSSION

The variation in biomass and nitrogen accumulation was significantly influenced by cover crop species, sowing date, years and their interaction (Table 2). Biomass accumulation was mainly influenced by cover crop species (53%) and sowing date (31%) in both years; for nitrogen it was 67 and 21%, respectively.

Table 2. Analyses of variance for cover crop biomass and nitrogen accumulation depending on cover crop species, sowing date, year and their interaction

Characteristic	Source of variation	df	SS	MS	F	p
Biomass	Year	1	2,358,755	2,358,755	75	0.000
	Cover crop	5	118,228,073	23,645,615	754	0.000
	Sowing date	3	69,540,674	23,180,225	739	0.000
	Crop x Year	5	4,399,229	879,846	28	0.000
	Crop x sowing date	15	13,866,705	924,447	29	0.000
	Sowing date x year	3	4,220,966	1,406,989	45	0.000
	Crop x year x sowing date	15	3,397,583	226,506	7	0.000
Nitrogen	Year	1	1,669	1,669	53	0.000
	Crop	5	154,195	30,839	980	0.000
	Sowing date	3	47,936	15,979	508	0.000
	Crop x Year	5	3,565	713	23	0.000
	Crop x sowing date	15	12,086	806	26	0.000
	Sowing date x year	3	4,836	1,612	51	0.000
	Crop x year x sowing date	15	2,598	173	6	0.000

Biomass and N accumulation of cover crops in 2017

In 2017, at the earliest sowing date (Aug 3), white mustard produced significantly highest DM yield (4,980 kg ha^{-1}) (Fig. 1). Similar amount of biomass (3,500–5,500 kg ha^{-1}) has been reported by Björkman et al. (2015), who concluded that mustard performed best in cool and moist conditions by producing higher biomass in autumn compared to spring planting. Earlier studies in Estonia reported white mustard's biomass of 2,500 kg ha^{-1} (Toom et al., 2017) and 3,000 kg ha^{-1} (Talgre et al., 2011). N accumulation by cover crops depends on the total amount of biomass produced and the percentage of N in the plant tissue. Due to its large biomass, white mustard accumulated significantly higher amount of N (128 kg ha^{-1}) (Fig 2). Faba bean had significantly higher biomass (3,050 kg ha^{-1}) than field pea (2,600 kg ha^{-1}), however their N accumulation (100 kg ha^{-1}) did not differ significantly. Similar biomass (1,570–1,870 kg ha^{-1}) and N (30–41 kg ha^{-1}) accumulation were recorded for phacelia, buckwheat and berseem clover.

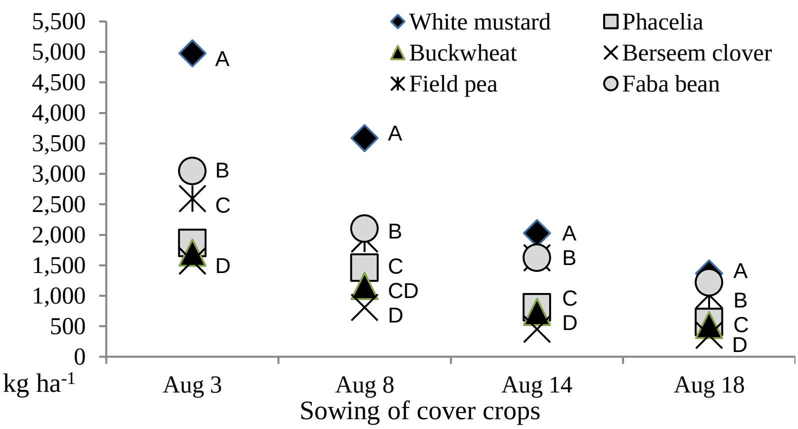

Figure 1. The biomass (above and below ground) production of cover crops (dry matter kg ha^{-1}) depending on date of sowing in 2017. Statistically significant differences ($p < 0.05$; *ANOVA, Fisher LSD test*) within the sowing date are marked with different letters.

At the sowing dates of Aug 8 and 14, white mustard's biomass decreased 28 and 59%, respectively, from the first sowing date. It produced significantly higher amount of biomass (3,590 and 2,030 kg ha^{-1}, respectively) of all species. At the same sowing dates, there was no significant difference between the biomass of field pea and faba bean (1,940–2,100 and 1,620 kg ha^{-1}, respectively).

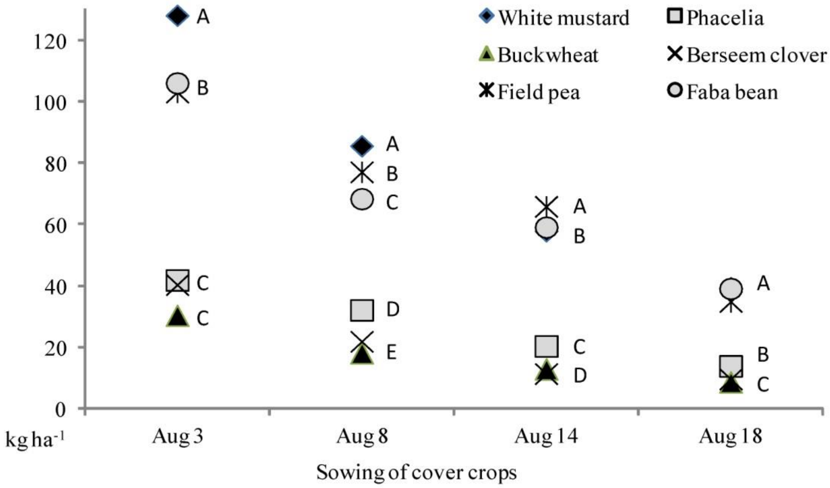

Figure 2. The nitrogen accumulation of cover crops (N kg ha^{-1}) depending on date of sowing in 2017. Statistically significant differences ($p < 0.05$; *ANOVA*, *Fisher LSD test*) within the sowing date are marked with different letters.

By the last sowing date (Aug 18), white mustard (73% reduction from the first sowing date) and faba bean (60% reduction) produced significantly higher biomass (1,220–1,370 kg ha^{-1}), followed by field pea (1,000 kg ha^{-1}). All these three species produced significantly higher amount of N (35–40 kg ha^{-1}) compared to other tested cover crops.

At second planting date (Aug 8), phacelia's and buckwheat's biomass decreased 22 and 32%. At later sowings Aug 14 and 18, it was reduced sharply (57 and 70%, respectively), producing biomass of 520–570 kg ha^{-1} by last sowing date. One of the reason of Buckwheat's low yield was the damage by frosts that occurred at the end of September. In other studies, buckwheat has shown rapid growth in the beginning of the growing season, but in some years, lower yield is explained by sensitivity to the irregular rainfall and low ground temperatures that end its growth (Handlířová et al., 2017). Conversely, phacelia has been recommended as one of the least sensitive cover crop to delayed sowing (Zaniewicz-Bajkowska et al., 2013) and unfavourable temperature and rainfall conditions (Handlířová et al., 2017). Berseem clover produced significantly lowest biomass at Aug 8, 14 and 18 sowings. At the second sowing date it was reduced already 49%. By the last sowing date, the biomass decreased 77%, resulting in yield of 360 kg ha^{-1} and the nitrogen accumulation of only 10 kg ha^{-1}.

Biomass and N accumulation of cover crops in 2018

In 2018, because of the dry soil conditions, cover crops sown at first (Aug 3) and second (Aug 8) planting dates had no differences in biomass as well as in N accumulation. As in the previous year, white mustard produced significantly higher (3,790–3,810 kg ha^{-1}) biomass compared to other species (Fig. 3). The lower biomass yield compared to 2017 was possibly associated with warm temperatures that caused earlier flowering and reduced root activity and nutrient uptake (Talgre et al., 2011). Legumes faba bean and field pea were not affected by drought and produced similar biomass as in the previous year (Fig. 4). Faba bean had significantly higher yield (3,230–3,340 kg ha^{-1}) compared to field pea (2,660–2,690 kg ha^{-1}), however their N accumulation value did not differ significantly and was precisely the same as in the previous year (100 kg ha^{-1}). Studies have shown that faba bean sown at early August produced 100 kg ha^{-1} N (Talgre et al., 2011; Zaniewicz-Bajkowska et al., 2013) and in favourable conditions even 192 kg ha^{-1} N (Etemadi et al., 2018). Our results showed that Phacelia produced 2230 kg ha^{-1} of biomass and accumulated 46 kg ha^{-1} N, which were higher than in the previous year. Zaniewicz-Bajkowska et al. (2013) reported much higher biomass (5,500 kg ha^{-1} DM) and N accumulation (90 kg ha^{-1}) of phacelia in Poland, sown on 4th of August. Buckwheat's biomass was practically the same as in 2017 (1,650 kg ha^{-1}), with N accumulation of 27 kg ha^{-1}. Significantly lower yield (720 kg ha^{-1}) and N accumulation (18 kg ha^{-1}) compared to other species was found in berseem clover. Clark et al. (2012) concluded that poor seedling emergence and reduced growth of berseem clover are caused by dry and warm conditions before sowing.

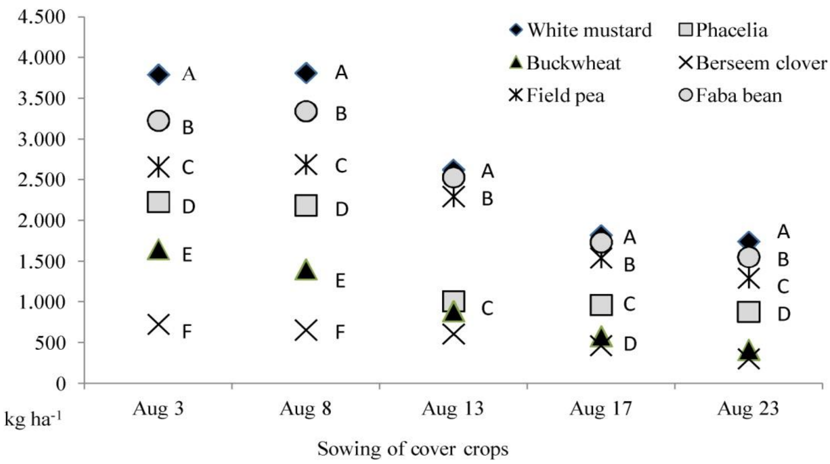

Figure 3. The biomass (above and below ground) production of cover crops (dry matter kg ha^{-1}) depending on date of sowing in 2018. Statistically significant differences ($p < 0.05$; *ANOVA, Fisher LSD test*) within the sowing date are marked with different letters.

At sowing dates Aug 13–23, white mustard (2,620–1,740 kg ha^{-1}), faba bean (2,530–1,550 kg ha^{-1}) and field pea (2,290–1,290 kg ha^{-1}) were the best biomass producers and N accumulators (90–50 kg ha^{-1}). Because of the smaller decrease at later sowings compared to the previous year, it can be concluded that these species were not negatively affected by low rainfall and they preferred warmer temperatures. The yield of phacelia and buckwheat was reduced sharply from Aug 13, whilst it stayed nearly the same at sowing dates of Aug 17 and 23 (960 and 880 kg ha^{-1}). As in the previous year, buckwheat was damaged by night frosts, and by last sowing date its biomass yield was only 410 kg ha^{-1}, which was not significantly different from berseem clover (300 kg ha^{-1}). Both crops accumulated only 7–8 kg ha^{-1} N. Buckwheat and phacelia are valued because of their weed suppression ability and disease resistance (Brust et al., 2014; Björkman et al., 2013). Earlier studies have also demonstrated their ability to solubilize and take up phosphorus that is otherwise unavailable to crops and release it to subsequent crops (Eichler-Löbermann et al., 2009; Teboh & Franzen et al., 2011). Therefore these species could be used in a mixture with other species that produce higher biomass.

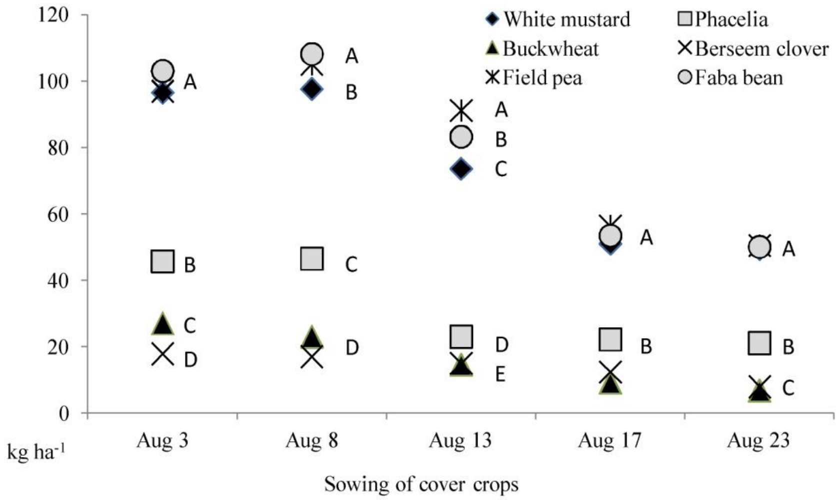

Figure 4. The nitrogen accumulation of cover crops (N kg ha^{-1}) depending on date of sowing in 2018. Statistically significant differences ($p < 0.05$; *ANOVA*, *Fisher LSD test*) within the sowing date are marked with different letters.

Although the poor emergence and growth of berseem clover was caused by unfavourable weather conditions, it also showed rapid biomass reduction in the previous year when sown after the first week of August. It can be concluded that Estonian weather conditions in the fall are not favourable for berseem clover. However, when sown in spring, berseem clover produces high biomass and can be used as a green manure crop before winter cereals (Tamm et al., 2016). However, when sowing of berseem clover is performed early August and weather conditions are not as extremely dry as in 2018, it might be a valuable addition to other cover crop species used here in Estonia. This is in accordance with Ghaffarzadeh (1997) who found that berseem clover is suitable for mixing cropping to increase total DM yields and subsequent crop yield.

CONCLUSIONS

The two year experiment showed that biomass and N accumulation of cover crops were reduced with delayed sowings, but the reduction mainly depended on cover crop species.

In 2017 with moderate temperatures and high rainfall conditions, cover cop biomass was reduced with all delayed sowings (Aug 8–18). In 2018, because of lack of soil moisture before sowing, cover crops sown at Aug 3 and 8 produced the same amount of biomass, but at later sowings (Aug 13–23) the biomass was reduced.

White mustard, field pea and faba bean accumulated significantly higher amount of biomass and N than phacelia, buckwheat and berseem clover at all sowing dates in both years. Although their biomass also decreased with delayed sowing dates, they accumulated adequate biomass and N in latest sowings. Phacelia's biomass decreased rapidly in both years, therefore the optimum sowing time should be until the middle of August. Buckwheat and berseem clover were the most susceptible to unfavourable weather conditions and their biomass decreased quickly in both years and can be recommended for sowing at the beginning of August

ACKNOWLEDGEMENTS. The research was supported by Estonian Ministry of Rural Affairs' project 'Varieties suitable for organic cultivation in Estonia' (10.1-2/430 p.4; PA1-RUP-026) and by 'Designing of an agrotechnical system including evaluation of suitable catch crop species, their seed mixtures and their cultivation methods' (T170143PKTM).

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