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Article

Response of Field Pea and Common Vetch, Grown as a Catch Crop, on the Sowing Method

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Abstract: In temperate climate zones, long periods without rainfall or with excessive rainfall are common during sowing and the initial vegetation of a catch crop. These periods can result in poor emergence and/or low yields. The study aimed to determine the influence of the depth of furrow sowing of catch crops on the soil moisture in the immediate vicinity of the seeds sown (1), dynamics of germination and plant emergence (2), and the biomass yield (3). Three furrow sowing depths (4–5 cm FS-S, 6–7 cm FS-M, and 8–9 cm FS-D) were tested and compared with traditional sowing (TS) in the cultivation of field pea and spring vetch catch crops. High amounts of precipitation were stated in the study period, especially in years 2016 and 2017. Furrow sowing enabled placing seeds in soil layers characterized by higher moisture content than traditional sowing. The sowing method did not significantly affect the plant density in any of the three years of the study. Field pea turned out to be a more valuable species for cultivation in catch crops in conditions with excessive precipitation. This plant produced a significantly greater yield of above-ground dry matter and total biomass than spring vetch. The sowing method did not affect the yield of catch crop biomass in study conditions.

Keywords: legume; furrow sowing; soil moisture; dynamics of germination; pea; vetch

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1. Introduction

Catch crops are currently valued mainly due to their beneficial effect on the soil environment. This manifests itself in an improvement of the physical and biological properties of the soil [1,2] and in reducing the risk of eutrophication caused by leaching of nutrients from the soil [3]. In addition, extending the period in which plants absorb atmospheric CO_2 and increasing the carbon content in the soil by leaving in situ the biomass of the roots and above-ground parts of catch crops reduces the growth of CO_2 in the atmosphere by about 150–300 kg ha^{-1} year^{-1} C [4]. A catch crop can absorb 60–240 kg ha^{-1} nitrogen and 160–310 kg ha^{-1} potassium from the soil and gradually release them in available forms for successive crops [3,5–7]. The dry matter yield of the above-ground parts of plants grown as a catch crop can be 2.0–5.5 Mg ha^{-1} [3].

With the currently used sowing technique, obtaining a biomass yield with significant importance for the uptake and protection against leaching of the components released during the mineralization of soil organic matter in the summer and autumn period is possible only with favourable weather conditions. Temperate climate zones with a variable distribution of atmospheric precipitation can give rise to a problem in the cultivation of catch crops, which is poor seed germination caused by frequent water deficiencies in the soil during the sowing and germination periods. A no less important problem during the time of initial plant growth and development may be excess rainfall, which has the effect of limiting the access of germinating seeds to oxygen [8,9]. Decreasing O_2 availability results in a gradual decrease in the germination rate [10]. According to Wiraguna [9], field pea fail to germinate under conditions of low oxygen concentration, often due to the limitation of protein synthase during imbibition.

Due to the high variability of yearly weather conditions, the cultivation of plants such as catch crops can be at high risk. In the years with a shortage of rainfall in July and August, seed germination can be unsatisfactory. On average, once every five years in the central part of Poland, the conditions for germination and emergence of plants are so unfavourable that the plantations must be liquidated [11,12]. A solution to this problem may be the use of furrow sowing in the cultivation of catch crops. This consists of sowing seeds in a seedbed, which is the open bottom of a furrow that is formed 6–8 cm deep with a properly weighted coulter [13]. For sowing in accordance with the assumptions of this technique, a seeder with coulters with an increased wing spread angle and disassembled furrow scrapers is used [14]. Optimum soil moisture conditions during germination enable faster and fuller emergence. This allows for faster penetration of the soil by the roots, improving the rate of growth and development of plants, creating a chance to produce a higher yield.

In the current conditions of agricultural production, dominated by cereals, a very important role is played by the appropriate selection of species for cultivation as a catch crop. Legume crops that have a positive effect on the chemical and physical properties of the soil are the most desirable [15,16]. Legume crops grown as a catch crop require an early sowing time [17]. A species with a relatively high tolerance for delaying sowing until about August 10th is the field pea [15]. However, it is a plant with large seeds, and therefore requires a large volume to be sown. An alternative to peas can be common vetch, characterized by smaller seeds and 60% lower sowing rate. This plant produces a delicate and protein-rich vegetative mass [18].

The research hypothesis assumed that the selection of the appropriate depth of furrow sowing would enable optimization of the moisture content of the seedbed and that the reaction of seeds to the seedbed moisture will be dependent on plant species.

The aim of our study was to determine the influence of the depth of sowing of the field pea and spring vetch, grown as a catch crop, on the soil moisture in the immediate vicinity of the seeds sown (1), dynamics of germination and plant emergence (2), as well as yield of aboveground biomass and post-harvest residues (3).

2. Materials and Methods

2.1. Experiment Site

The field experiments were carried out in 2016–2018, at the Research Station of the Faculty of Agriculture and Biotechnology in Mochełek (53°13′ N; 17°51′ E) (Figure 1).

The experiment was conducted on loam sand texture luvisol soil (LV) [19]; the previous crop was winter wheat. The content of absorbable forms of P and K was 70.5 and 147.7 mg kg^{-1}, respectively, and soil pH (1 mol dm^{-3} KCl) was between 6.8 and 7.2.

Figure 1. Site of field experiment at Mochełek, Kuyavian–Pomeranian voivodeship, Poland [20,21].

2.2. Experiment Design

A strict, two-factor field experiment was carried out in a randomized sub-block design.
Experimental factors:

Factor I—sowing method and depth:

TS—traditional sowing—depth approx. 3–5 cm,
FS-S—shallow furrow sowing—depth: 4–5 cm;
FS-M—medium deep furrow sowing—depth: 6–7 cm;
FS-D—deep furrow sowing—depth: 8–9 cm (Figure 2).

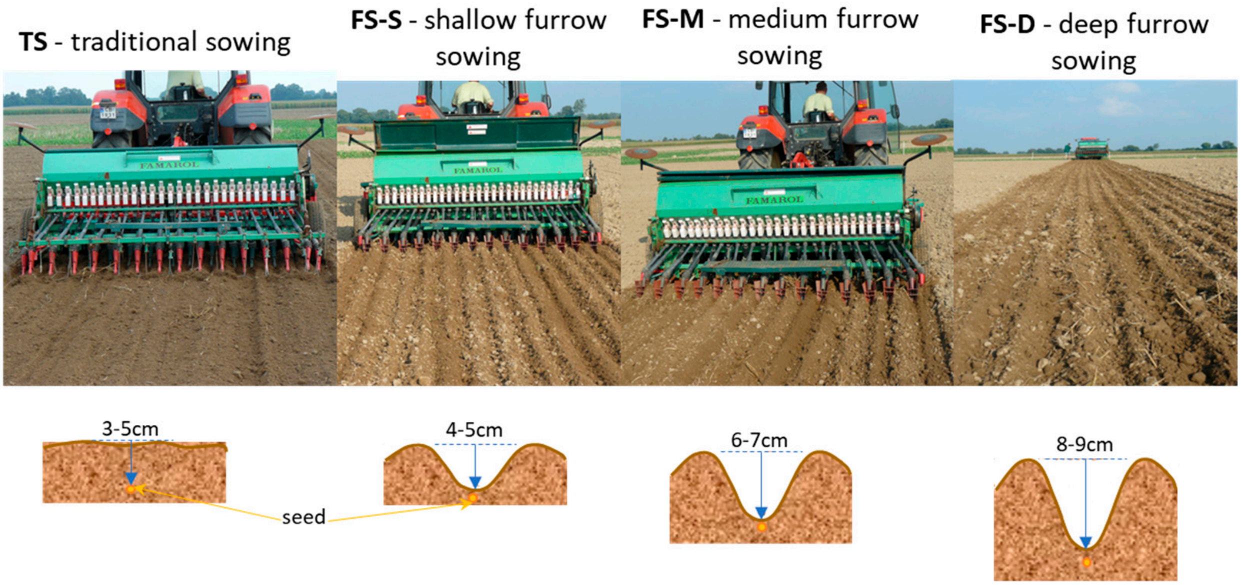

Figure 2. Sowing method and depth.

Factor II—plant species grown in catch crop: field pea; spring vetch.

Combinations of both factors constituted experimental objects (eight objects) in four replications (32 plots). A single plot was 3 m·10 m = 30 m^2.

2.3. Elements of Agrotechnical Practices

Catch crops were sown with the Famarol seed drill. In the case of furrow sowing, coulters with a widened wingspan angle and disassembled furrow scrapers were used [14].

The 'Hubal' cultivar of the field pea was sown in the amount of 255 kg ha^{-1}. Spring vetch 'Hanka' cultivar was sown in the amount of 110 kg ha^{-1}.

Catch crops were cultivated without the use of fertilization or chemical plant protection.

2.4. Samples and Measurements

In the period from sowing to the end of plant emergence, the soil moisture content was measured at the depth of the sown seeds. These measurements were made using the FDR method of the WET-1 probe and the HH2 reader (Delta-T Devices), immediately after sowing and at 3, 5, and 8 days after sowing. During vegetation, the course of plant development was monitored, the dates of the emergence of development phases, the dynamics of germination, and emergence of plants were determined—plant density was measured 5, 10, and 15 days after sowing. Catch crops were harvested in the second half of October. After harvesting, green mass samples were taken, on the basis of which the dry matter yield of plants was determined. The yield of post-harvest residues was determined on the basis of 25 × 25 × 25 cm soil monoliths taken from each plot.

2.5. Data Analysis

Single year data concerning all characteristics of soil and plants were calculated using two-way ANOVA in a four reps (block) model. The post-hoc calculation according to HSD Tukey's test ($p = 0.05$) was used for the separation of means of soil and plant traits.

3. Results

During the three-year period of the research, different weather conditions occurred, especially with regard to the rainwater supply to germinating field pea and spring vetch seeds (Table 1). In July and August 2016, the sums of precipitation were higher than the long-term average, which provided catch crops with sufficient water during the period of initial growth and development. Despite relatively high amounts of rainfall, there was no delay in harvesting the prior winter wheat, which made it possible to sow the catch crops on 8 August 2016. Precipitation in July and August 2017 was twice as high as the long-term average for the study area. This contributed to a delay in harvesting the previous crop. As a consequence, the catch crops were not sown until 11 August 2017. On the first day after sowing, very intense rainfall occurred, which resulted in blurring of the ridges in the plots with furrow sowing. Precipitation in August and September 2018 was only 43% of the long-term average for these months.

Table 1. Precipitation and air temperature (2016–2018) at the site of the field experiment.

	2016	2017	2018	2016–2018	1949–2018	2016	2017	2018	2016–2018	1949–2018
Month	**Precipitation—Sum [mm]**					**Temperature—Mean [°C]**				
July	133.8	118.9	86.0	112.9	74.4	18.3	17.7	20.5	18.8	18.2
August	55.3	126.1	23.7	68.4	53.0	16.4	17.7	19.9	18.0	17.6
September	19.4	78.4	17.0	38.3	41.4	14.3	13.1	15.6	14.3	13.2
October	116.3	106.8	34.1	85.7	32.5	6.3	10.1	9.8	8.7	8.3
Sum/mean VII–X	324.8	430.2	160.8	305.3	201.3	13.8	14.7	16.5	15.0	14.3

The individual years differed significantly in terms of thermal conditions during the study period (Table 1). In 2016, the air temperature in August and October was significantly lower than the long-term average. In 2017, the thermal conditions in August and September were close to the long-term averages for these months, while October this year was much warmer than the average for this region. In 2018, during the entire vegetation period of the catch crops, the air temperatures were significantly higher than the multi-year average (Table 1).

The sowing method had a small influence on the soil properties as well as on the studied features of catch crops (Table 2). A significant effect was found only in relation to the moisture content of the seedbed at 8 days after sowing. With regard to most of the traits, there was also no interaction of the sowing method with the years of research (except for the yield of green mass). On the other hand, an interaction was demonstrated between the species of the plant grown in the catch crop and the years of research in relation to most of the studied traits (except for the moisture content of the seedbed immediately after sowing and at 5 days after sowing).

Soil moisture in the vicinity of the sown seeds depended on the species cultivated in the catch crop, although an interaction of this feature with the years of research was found (Table 2). The plant density at 10 and 15 days after sowing also depended on the plant species. Particular catch crops showed different yield potential of both above-ground parts and post-harvest residue. An interaction was demonstrated between the research factors in shaping the moisture of the seedbed immediately after sowing, the plant density at 10 and 15 days after sowing, and the yield of green mass (Table 2).

Table 2. Statistical differences (*F*-values and significance level) between means of variables by two-way ANOVA with factors of catch crop species and sowing technology.

Characteristic	Variation Source	Sowing Technology (d.f. = 3)	Catch Crop Species (d.f. = 1)	Interactions: Catch Crop Species × Sowing Technology (d.f. = 3)
Seed bed moisture after sowing	Factor	1.80 NS	1.10 NS	3.55 *
	Factor × years	0.82 NS	1.13 NS	7.41 ***
Seed bed moisture 3 days after sowing	Factor	4.21 **	13.40 ***	2.26 *
	Factor × years	1.07 NS	11.80 ***	4.03 **
Seed bed moisture 5 days after sowing	Factor	0.99 NS	7.66 **	1.49 NS
	Factor × years	0.76 NS	1.47 NS	5.38 ***
Seed bed moisture 8 days after sowing	Factor	10.03 **	7.73 **	1.79 NS
	Factor × years	3.01 *	18.83 ***	5.07 ***
Plant density 10 days after sowing	Factor	1.94 NS	1651.64 ***	7.06 ***
	Factor × years	0.77 NS	307.88 ***	8.22 ***
Plant density 15 days after sowing	Factor	1.39 NS	2334.60 ***	8.93 ***
	Factor × years	0.46 NS	390.94 ***	6.62 ***
Green mass yield	Factor	0.41 NS	216.07 ***	3.76 *
	Factor × years	3.92 **	152.43 ***	11.93 ***
Dry mass yield	Factor	0.18 NS	176.13 ***	2.46 NS
	Factor × years	1.18 NS	33.27 ***	3.53 **
Fresh mass of post harvest residues	Factor	0.40 NS	63.73 ***	0.67 NS
	Factor × years	0.30 NS	14.32 ***	1.29 NS
Dry mass of post harvest residues	Factor	0.14 NS	30.12 ***	0.55 NS
	Factor × years	0.59 NS	4.92 *	1.84 NS

NS, not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; d.f., degree of freedom.

The sowing method and the species grown as a catch crop were of significant importance for the moisture content of the seedbed during the emergence period (Table 2, Figure 3). This influence was not found immediately after sowing and it was variable in the remaining measurement days. At 3 days after sowing, the moisture content of the seedbed in the plots with field pea was lower, while at 5 and 8 days after sowing it was higher than in the plots with spring vetch. At 3 and 8 days after sowing the moisture content of the seedbed in the plots with furrow sowing was higher than in the plots with traditional sowing. However, at 3 days after sowing, these differences were only significant for FS-M. A significant interaction of the species cultivated in the catch crops and the sowing method was found to also interact with the years of research. In 2016, however, an interaction was found between the factors in shaping the moisture of the seedbed immediately after sowing (Figure 4A). Moisture of the seedbed of the field pea catch crop was significantly higher after the application of FS-D than FS-M. In the case of the spring vetch catch crop, the sowing method did not significantly affect this feature. Moreover, the moisture content of the seedbed with the FS-D application was significantly higher in the field pea catch crop than in the spring vetch. On the other hand, in the remaining sowing variants, the type of catch crop did not affect this feature. In 2017, the average moisture content of the seedbed immediately after sowing was 5.37 percentage points higher than in 2016. A significantly higher value of this feature was found in the objects with the spring vetch catch crop after the application of FS-S than with TS (Figure 4B). In the field pea catch crop, no significant effect of the sowing method on the moisture content of the seedbed was found immediately after sowing. In 2018, the seedbed moisture content was 8.82 percentage points lower than in 2017. At this time, no significant influence of the experimental factors on the moisture of the seedbed was found (Figure 4C). There were also no interactions between research factors in shaping this feature. The synthesis of three years of research showed an interaction between factors in shaping this feature. In the objects with FS-D, a significantly higher moisture content of the seedbed in the catch crop from the field pea than from the spring vetch was demonstrated (Figure 4D). Among the other sowing methods, no significant influence of the species grown in the catch crop on this trait was found.

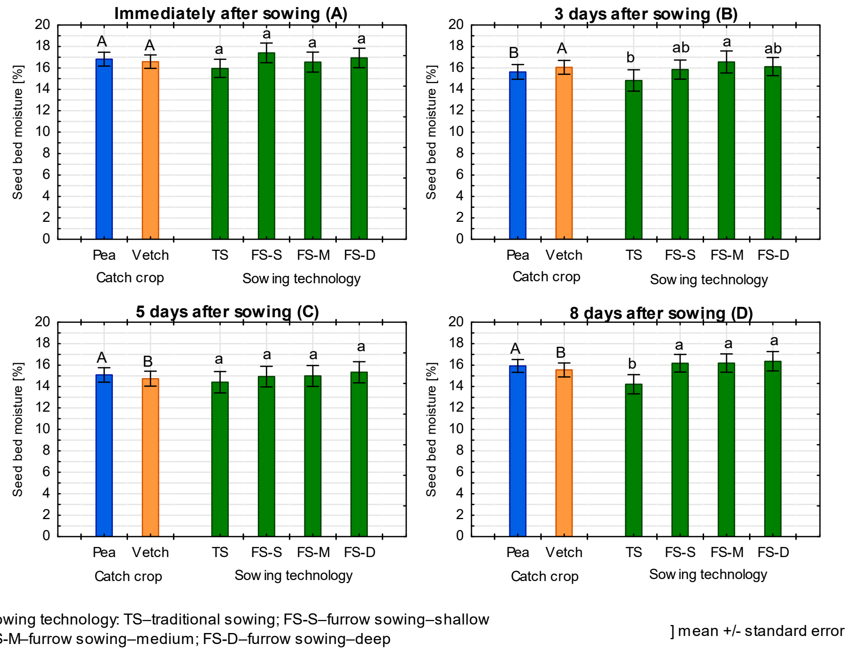

Figure 3. Seed bed moisture content during seed germination [% vol]—average for 2016–2018. a,b—the same small letter for different sowing methods indicates the lack of significant differences between means (p = 0.05). A,B—different capital letter for different crops indicates significant differences between means (p = 0.05).

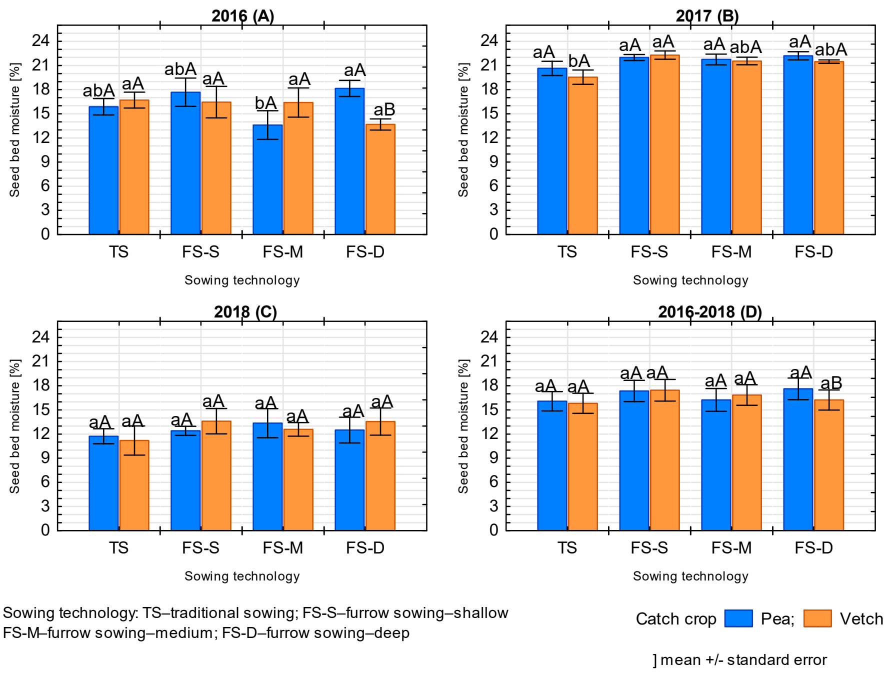

Figure 4. Interaction between research factors in shaping seedbed moisture immediately after sowing seeds [% vol]. a,b—homogenic groups HSD (p = 0.05) interaction for sowing method/species (the differences between the four methods of sowing separately for pea and for vetch); A,B—homogenic groups HSD (p = 0.05) interaction for species/sowing method (differences between pea and vetch for each sowing method).

The seed bed moisture content 3 days after sowing was also significantly dependent on the year of the study. It was high in 2017 and low in 2018 (Figure 5). In 2016 and 2017, no significant influence of the experimental factors on seedbed moisture was demonstrated and no interactions between experimental factors in shaping this trait were found (Figure 5A,B). In 2018, the method of sowing seeds also did not significantly affect the moisture content of the seedbed. On the other hand, significantly higher values of this trait were demonstrated in objects with spring vetch rather than field pea as a catch crop (Figure 5C). However, this effect was found only in FS-D. On average, in the three-year period of the study, a significant effect of the sowing method on the moisture content of the seedbed was demonstrated, and it was significantly higher with the application of FS-M than it was with TS (Figure 5D). Moreover, significantly higher moisture content of the seedbed was found in objects with the spring vetch than with the field pea catch crop. However, the influence of the species grown as the catch crop was found only in FS-M and FS-D.

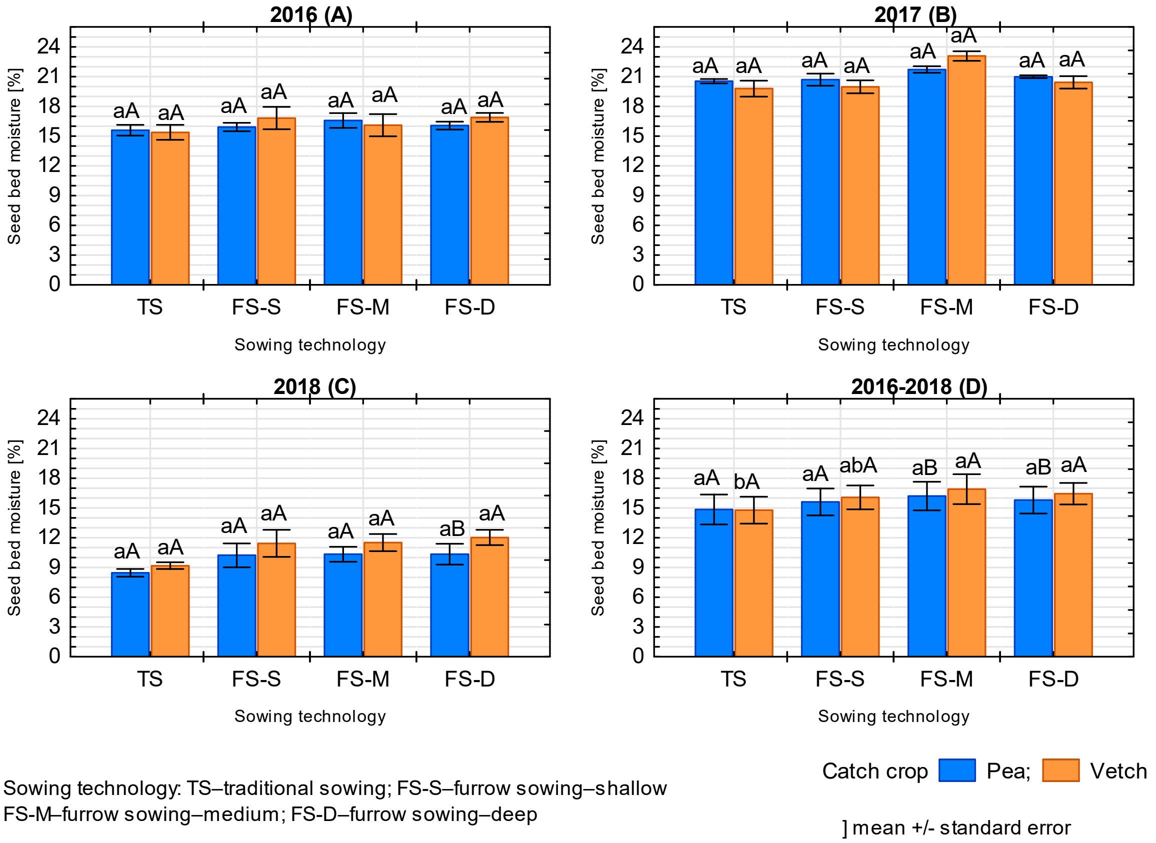

Figure 5. Seedbed moisture three days after sowing the seeds [% vol]. a,b—homogenic groups HSD (p = 0.05) interaction for sowing method/species (the differences between the four methods of sowing separately for pea and for vetch). A,B—homogenic groups HSD (p = 0.05) interaction for species/sowing method (differences between pea and vetch for each sowing method).

The experimental factors had a much greater effect on the seedbed moisture content measured 8 days after sowing (Figure 6). In 2016, under the conditions of an average moisture content of the seedbed at the level of 15.9%, a positive effect of furrow sowing, especially in FS-D, was demonstrated. However, no dependence of the seedbed moisture content on the species cultivated in the catch crop was demonstrated in this period (Figure 6A). In 2017, in the conditions of the high moisture content of the seedbed on the 8th day after sowing, no significant effect on this trait was found for any of the examined factors (Figure 6B). In 2018, the sowing method did not affect the moisture content of the seedbed on the 8th day after sowing (Figure 6C). On the other hand, significantly higher moisture content was found in the plots with field pea than in those with spring vetch. However, this impact was found only in the TS and FS-S. On average, during the three-year study period, a positive effect of furrow sowing on the moisture of the seedbed was demonstrated (Figure 6D). It was also shown that the seedbed moisture content was significantly higher in the plots with field pea than in plots with spring vetch. However, the effect of the catch crop on this characteristic was significant only in TS.

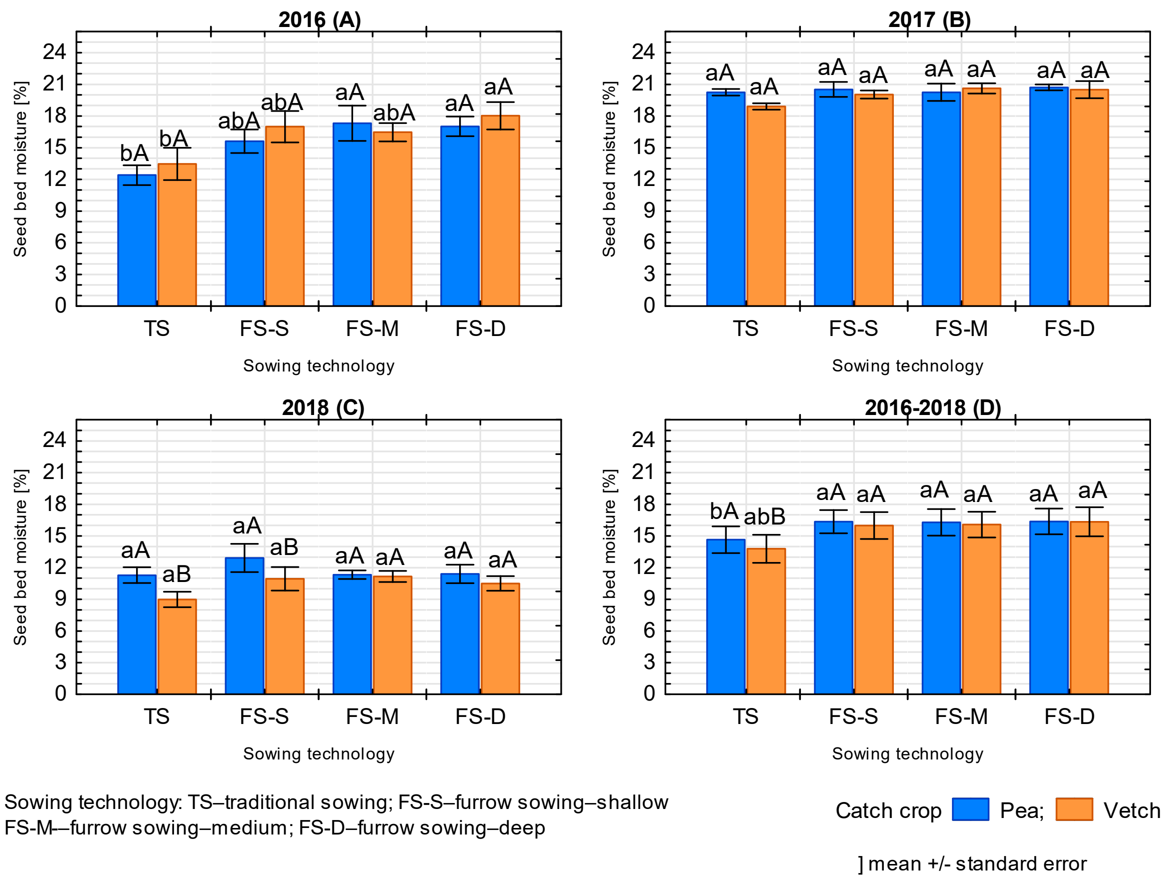

Figure 6. Seedbed moisture eight days after sowing the seeds [% vol]. a,b—homogenic groups HSD (p = 0.05) interaction for sowing method/species (the differences between the four methods of sowing separately for pea and for vetch). A,B—homogenic groups HSD (p = 0.05) interaction for species/sowing method (differences between pea and vetch for each sowing method).

In the first planned date of measurement of the plant density (5 days after sowing), no emergence was found in any of the three years of the study. The measurement carried out 10 days after sowing showed the dependence of the plant density on the species grown as a catch crop and the year of the study (Figures 7 and 8). The plant density 10 days after sowing was 87.8% of the plant density measured 5 days later. The density of spring vetch was significantly higher than that of field pea. On average, for the 3 years of the study there was no significant effect of the sowing method on the plant density of the catch crops. In the first year of research the number of plants per unit area was the highest. In all years, the spring vetch density was significantly higher than that of field pea (Figures 7 and 8). The sowing method did not significantly affect the plant density in any of the three years of the study. In 2018, an interaction between experimental factors with regard to this trait was found (Figure 8C). In the objects with the catch crop of spring vetch, no effect of the sowing method on the plant density 10 days after sowing was found. However, in the case of field pea, it was significantly lower with the use of FS-S than it was with the use of TS. On average, over the three-year study period, FS-S also showed a significantly lower number of field pea plants within 10 days after sowing compared to TS (Figure 8D).

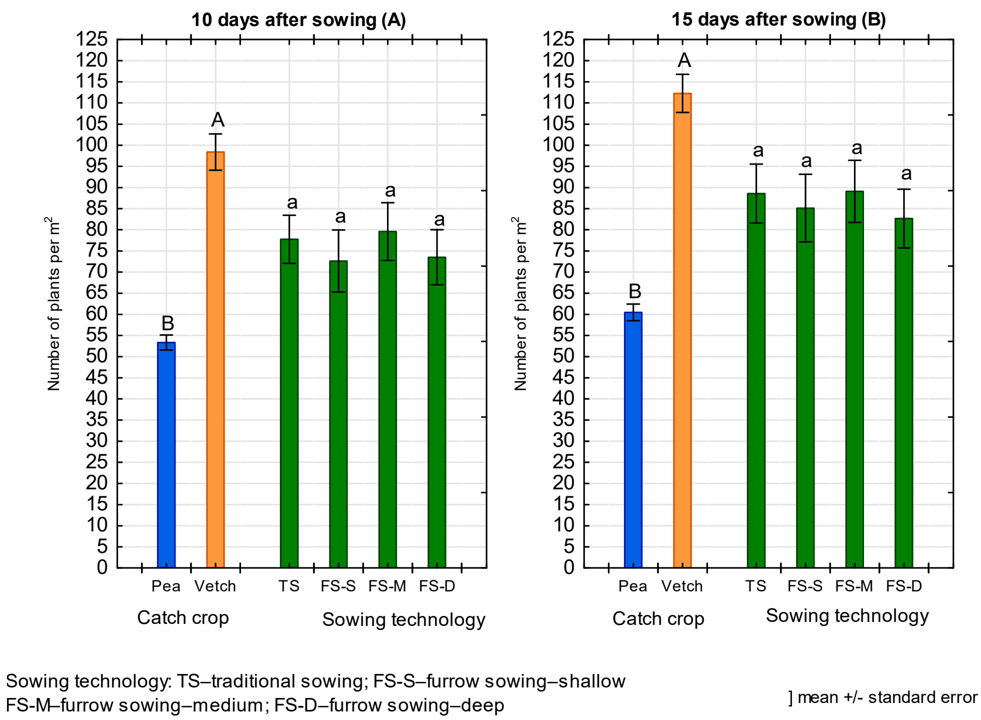

Figure 7. Plant density 10 (**A**) and 15 (**B**) days after sowing seeds [pcs·m^{-2}]—average for 2016–2018. a—the same small letter for different sowing methods indicates the lack of significant differences between means (p = 0.05). A,B—different capital letter for different crops indicates significant differences between means (p = 0.05).

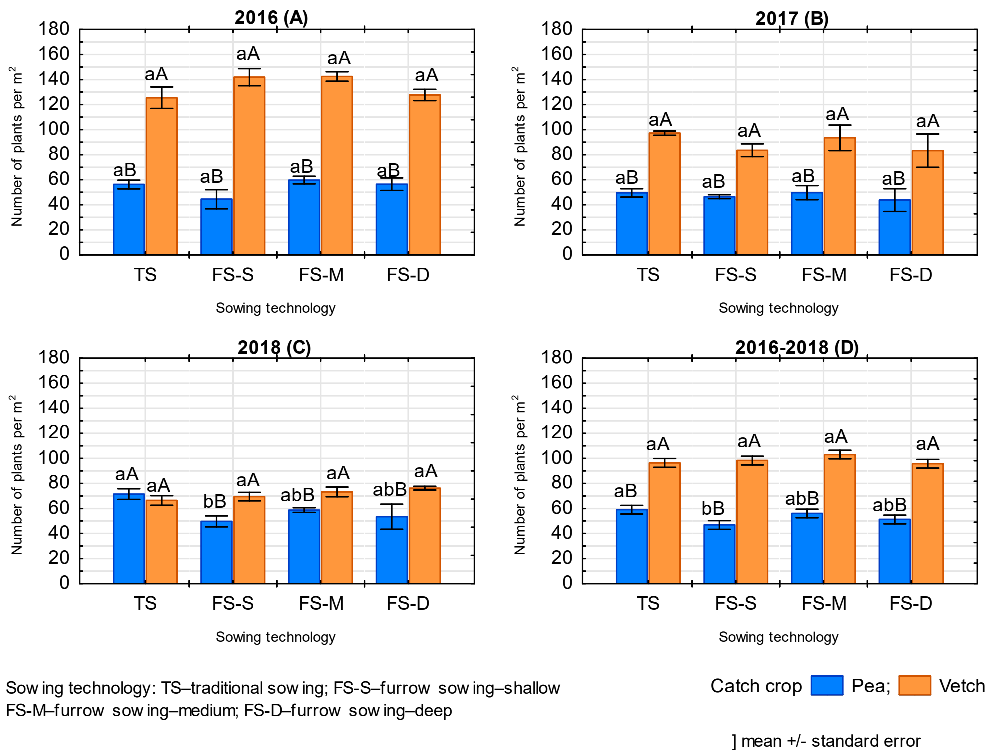

Figure 8. Interaction between factors in shaping the plant density 10 days after sowing seeds [pcs·m^{-2}]. a,b—homogenic groups HSD (p = 0.05) interaction for sowing method/species (the differences between the four methods of sowing separately for pea and for vetch). A,B—homogenic groups HSD (p = 0.05) interaction for species/sowing method (differences between pea and vetch for each sowing method).

The sowing method did not significantly affect the plant density within 15 days after sowing. Plant density at that time did not depend on the method of sowing catch crops in any of the three years of the study (Figure 9). The number of plants of the spring vetch was significantly higher than that of the field pea. There were no interactions between the factors studied in relation to the plant density measured 15 days after sowing.

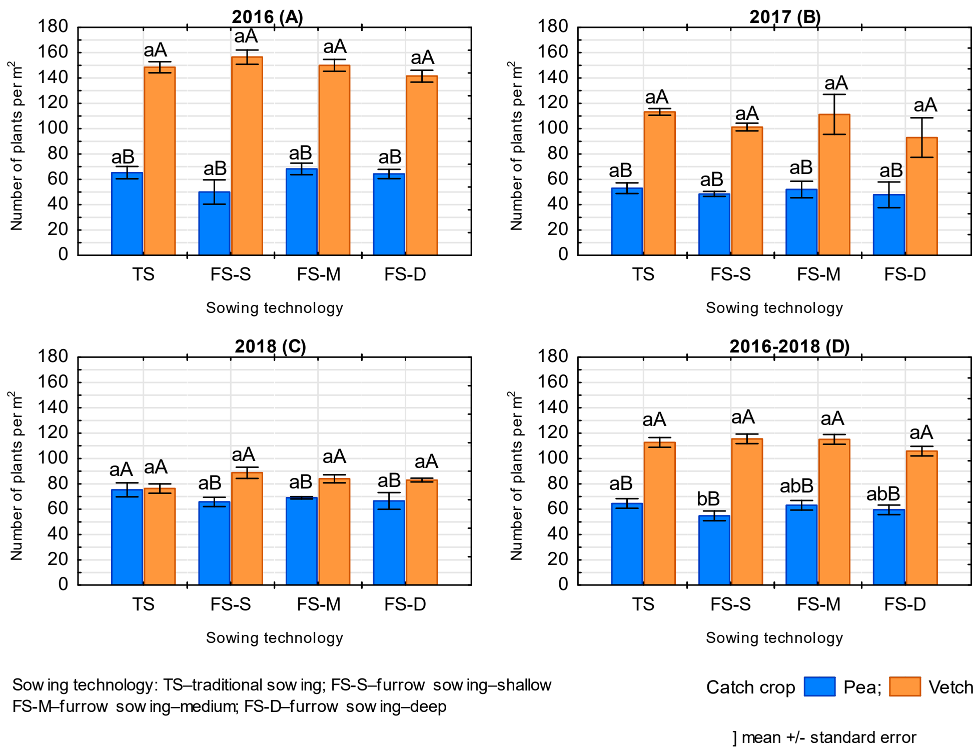

Figure 9. Interaction between factors in shaping the plant density 15 days after sowing seeds [pcs·m^{-2}]. a,b—homogenics groups HSD (p = 0.05) interaction for sowing method/species (the differences between the four methods of sowing separately for pea and for vetch). A,B—homogenic groups HSD (p = 0.05) interaction for species/sowing method (differences between pea and vetch for each sowing method).

The field pea produced a significantly higher dry matter yield of the aboveground parts and a significantly lower dry matter yield of post-harvest residues than spring vetch (Figure 10A,B). The sowing method did not significantly affect the dry matter yield of the catch crops.

The influence of the experimental factors on the dry matter yield of the catch crops was found to be differentiated in the years observed (Figure 11). In 2016, the method of sowing did not affect the dry matter yield of the spring vetch, and in the case of the field pea, FS-S caused a significant reduction in the dry matter yield compared to the yield obtained under TS and FS-M conditions. In 2016 and 2017, field pea yielded significantly better than the spring vetch, and in 2018, no significant differentiation in the yield of the studied species was found. The means of the three-year research indicate a significantly better yield for field pea than for spring vetch. A higher yield of field pea was found in all sowing methods. Moreover, no significant effect of the sowing method on the yield of the catch crop was found for either of the plants tested.

The dry matter yield of the catch crop post-harvest residues did not depend on the sowing method (Figure 12). On average, spring vetch produced a significantly higher dry matter yield of post-harvest residues than field pea. In 2017 and 2018, the dry matter yield of post-harvest residues of field pea and spring vetch was at a similar level. The average total yield of dry biomass of field pea from three years of research was 17.2% higher than that of the spring vetch.

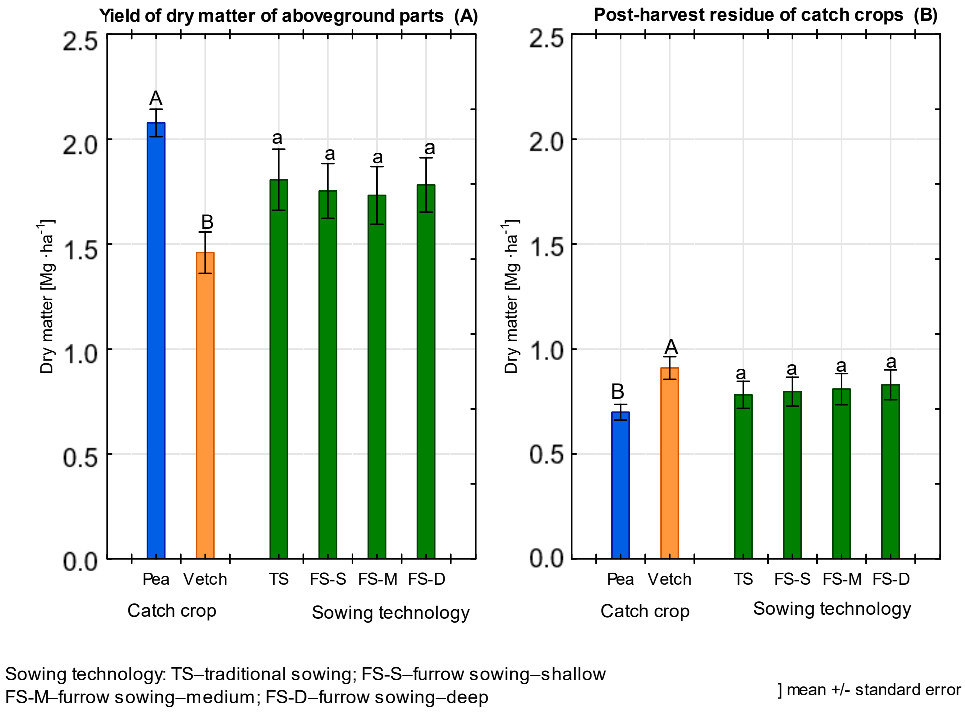

Figure 10. Yield of dry matter of aboveground parts and post-harvest residue of catch crops [Mg ha^{-1}]—average for 2016–2018. a—the same small letter for different sowing methods indicates the lack of significant differences between means (p = 0.05). A,B—different capital letter for different crops indicates significant differences between means (p = 0.05).

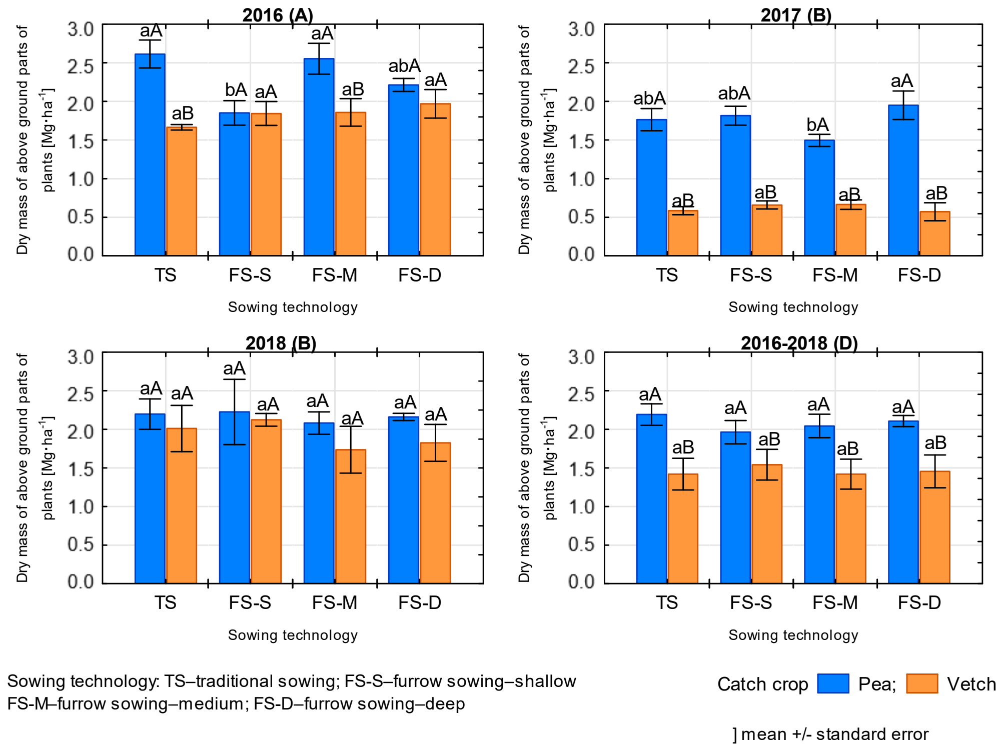

Figure 11. Interaction between factors in shaping the dry matter yield of catch crops [Mg ha^{-1}]. a,b—homogenic groups HSD (p = 0.05) interaction for sowing method/species (the differences between the four methods of sowing separately for pea and for vetch). A,B—homogenic groups HSD (p = 0.05) interaction for species/sowing method (differences between pea and vetch for each sowing method).

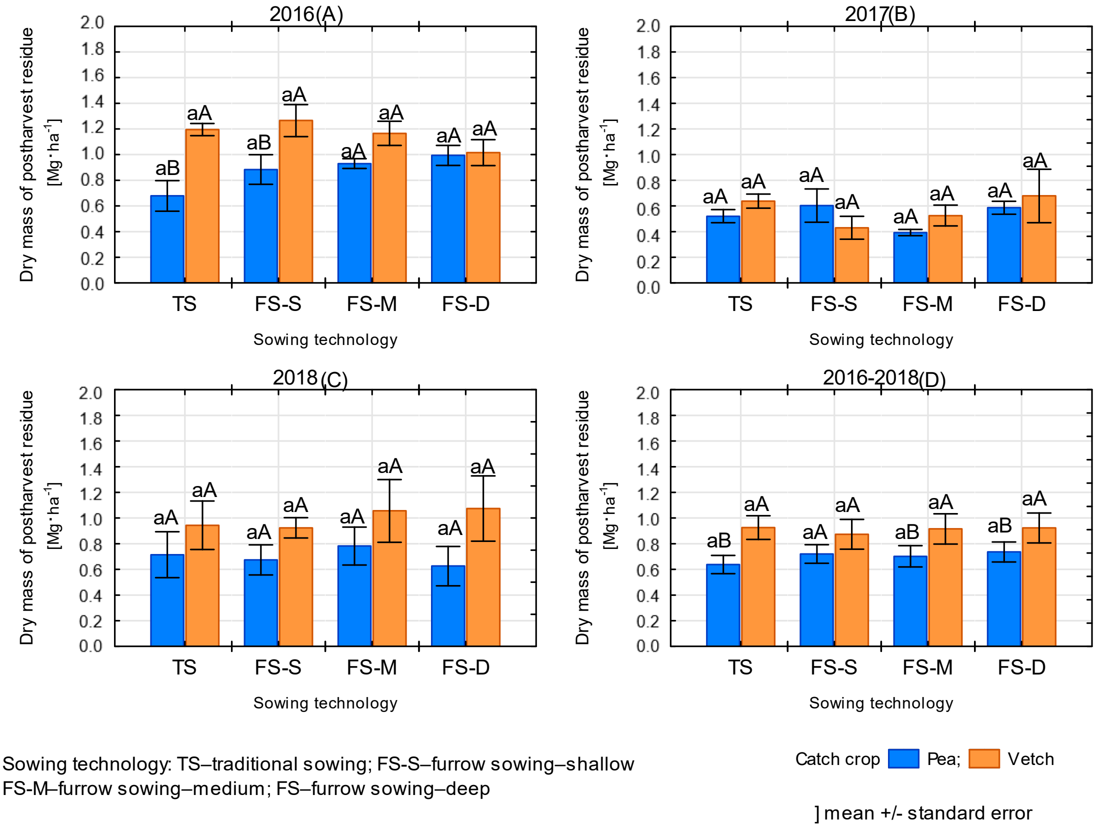

Figure 12. Interaction between factors in shaping the post-harvest residue dry mass yield of catch crops [Mg ha^{-1}]. a—homogenic groups HSD (p = 0.05) interaction for sowing method/species (the differences between the four methods of sowing separately for peas and separately for vetch). A,B—homogenic groups HSD (p = 0.05) interaction for species/sowing method (differences between peas and vetch for each sowing method).

4. Discussion

Furrow sowing is an innovative method of sowing, which makes it difficult to discuss our own results with the research of other authors. There are reports of the use of furrow sowing, but research was directed towards other cognitive goals [22]. Analogies can be found in the Strip-Till Mzuri pro till sowing technology [23], in which furrows are formed and the seedbed is located lower than the inter-row to which the soil is moved from a row. The authors of this cited study show that the emergence of winter oilseed rape in the strip tillage system is more even than in the case of traditional sowing. It also had a positive effect on the uniformity of the later development of plants. Such an effect can be attributed to the lower susceptibility of seeds sown in furrows to the negative impact of insufficient or excess rainfall, especially very rapid rainfall, having a destructive effect on the soil structure. This corresponds to the hypothesis put forward in the research carried out for the purpose of this manuscript. The availability of water for newly sown seeds is a critical factor for their rapid germination. In the case of catch crops, the availability of water is particularly important due to the high temperatures occurring during germination and initial growth period, and consequently, very large losses of moisture from the surface layer of the soil [24]. Moreover, due to the short period in which the biomass growth is intense [25], a delay in germination of plants grown in catch crops leads to a significant reduction in their yield. Simulation results from Constantin et al. [26] for France show that poor emergence of catch crops sown in early terms is caused by a lack of moisture in the soil, while later sowing in favourable rainfall conditions was more successful. The authors' own research published in this manuscript shows that furrow sowing enables obtaining an improvement in the moisture level of the seed surroundings. This is due to their placement in a deeper, and therefore wetter, layer of soil. The moisture measurements carried out showed that the conditions for germination in the plots with furrow sowing were more favourable than in the traditional plow cultivation. This was particularly visible in measurement on the 8th day after sowing. Despite the positive effect of furrow sowing on the moisture of the seedbed, it did not lead to improvement in plant density or biomass yield. Seed germination and plant growth and development went well in all objects of the study. This was due to the relatively high soil moisture levels during all of the sowing periods and the beginnings of vegetation, caused by a very high sum of rainfall preceding the sowing date (2018) and throughout each of the entire periods covered by the research (2016 and 2017). The optimum precipitation during the vegetation period of catch crops from legumes is 180–240 mm, of which, in the period July–August, should be 142–154 mm [12]. It turns out, therefore, that the above-mentioned model by Constantin et al. [26], in which the authors show that the conditions unfavourable for the emergence of catch crops occur only once every few years depending on the region—worked well for the conditions of central Poland. The negative effect of shallow furrow sowing on the number of field pea plants, obtained within 10 days after sowing, was a result of poor seed coverage caused by insufficient soil sliding down from the ridge walls under the influence of gravity. With furrow sowing applied at a greater depth, some seeds were also left uncovered with soil, but their number was much smaller. To improve the quality of furrow sowing, it would be necessary to apply a mechanism forcing the seeds to be covered with soil. This finding is partially consistent with what Baker [27] concluded. This is especially important for field peas, which are characterized by large seeds and high water requirements during germination [24]. Taking into account that 15 days after sowing, no dependence of the plant density on the sowing method was found, it can be concluded that incomplete seed coverage with soil during germination delayed plant development, but did not cause long-term negative consequences. Taking into account the obtained results, a modified coulter for furrow sowing was developed that was equipped with an element forcing increased soil sliding from the sides of the ridges [28].

Poor germination and low pea density in the years with high rainfall during germination (2016 and 2017) indicate excessive soil moisture in the vicinity of the seeds sown. According to Rajendran et al. [29], limitation of the air access to the seed during germination in conditions of excessive soil moisture leads to a reduction in the growth of roots and shoots. Particular genotypes of field pea differ in tolerance to soil waterlogging during germination. Most genotypes with a dark-colored testa (90%) were waterlogging tolerant, whereas those with a light-colored testa were all waterlogging sensitive [30]. Additionally, different seed sizes of individual plant species may explain the different reaction of vetch and field pea. According to Wiraguna [9], plants with large seeds are more vulnerable to oxygen deficiency, which limits seed germination in years with heavy rainfall. In addition, field pea was more exposed than vetch to this adverse effect of precipitation due to the greater depth of seed sowing. The seedbed humidity of 12.6% in 2018 was more favorable for field pea than the 16.1 and 21.4, found in 2016 and 2017, respectively. Large variation in terms of precipitation totals is typical for the region in which the research was conducted. Żarski et al. [31], based on an analysis of data from the years 1981 to 2010, found a particularly large variation in precipitation in August, in which the highest value was 210.5 mm (year 1985), while the lowest was only 12.0 mm (year 1992). This large variation in yearly precipitation is the reason for the significant risk for catch crop cultivation in the study area. Therefore, the correct sowing method and the selection of the plant species are very important.

The higher density of spring vetch plants compared to field pea was mainly due to the higher sowing density of vetch. It was therefore in line with expectations. However, the vetch was less sensitive to the negative aspects of furrow sowing. This could be due to the relatively low 1000-seed weight of spring vetch and, as a consequence, better soil coverage, sliding off the ridge.

The beneficial effect of deep furrow sowing on the dry matter yield of the field pea, found in 2017, confirms the need to improve the degree of soil coverage of seeds, which improved with the deepening of sowing. These yields were obtained in conditions of exceptionally high rainfall during the vegetation period of the catch crops in 2017. These conditions were unfavourable, especially for the spring vetch. The green mass yield of this crop amounted to only 32.3% of the field pea yield from that year. In 2016 it was only 8.1% lower, and in 2018 it was 4.3% higher than for the field pea. The reason for the large variation in 2017 could be the very intense rainfall that occurred a few hours after sowing and caused blurring of the ridges, which was more unfavourable for the spring vetch due to its smaller seeds. The study indicates that that further refinement of furrow sowing method is needed to improve seed coverage during sowing. Moreover tests of furrow sowing in the conditions of serious rainfall deficits are needed.

5. Conclusions

According to the research hypothesis, furrow sowing, regardless of the depth, made it possible to place the seeds in a wetter layer of the soil than traditional sowing. This was especially visible in measurement on the 8th day after sowing. The sowing method did not affect the dynamics of emergence or the plant density 10 and 15 days after sowing. Reaction on seedbed moisture was dependent on plant species. Field pea density after emergence in soil with 21.4% moisture content (2017) was lower than in 12.6% soil moisture conditions (2018). Higher soil moisture was more favorable for spring vetch germination. Field pea produced a significantly higher yield of aboveground dry matter and total biomass than spring vetch. The sowing method did not affect the dry matter yield of the above-ground parts and post-harvest residues of the catch crops.

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