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YIELDS OF SELECTED CATCH CROPS IN DRY CONDITIONS

Martina Handlířová[1], Blanka Procházková[1], Vladimír Smutný[1]

[1] Department of Agrosystems and Bioclimatology, Faculty of AgriSciences, Mendel University in Brno, Zemědělská 1, 613 Brno, Czech Republic

Abstract

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Catch crops mainly reduce soil erosion and leaching of nutrients as well as enrich the soil organic matter. The aim of this research is to evaluate the yields of catch crops of *Sinapis alba*, *Phacelia tanacetifolia*, *Fagopyrum esculentum*, *Carthamus tinctorius* and *Secale cereale v. multicaule*, and thus determine the possible applicability of catch crops in areas with high average annual temperature and low precipitation totals. The small-plot field experiment was performed on clay-loam gleyic fluvisol at the Field Experimental Station in Žabčice, Southern Moravia, Czech Republic, within the period of 2006-2014. The catch crops were set up after winter wheat in mid-August. The results have shown a statistically significant difference among different catch crops in yield of dry matter and even among years. The yield of catch crops is mainly dependent on a sufficient supply of water in the soil and the appropriate amount and distribution of rainfall over the growing season. *Sinapis alba* and *Phacelia tanacetifolia* regularly reached the highest yields. High yields were also achieved with *Fagopyrum esculentum*. Due to the method of crop rotation in the Czech Republic, with a predominance of *Brassica napus var. napus*, it is inappropriate to include *Sinapis alba*. It is the best to grow *Phacelia tanacetifolia* and even *Fagopyrum esculentum*, or a mixture thereof, depending on the use of catch crops.

Keywords: catch crops, drought, yield

INTRODUCTION

Climate change is a phenomena which directly influences crop production. The increased occurrence of intense rainfall can mean an increased risk of water erosion of soil. As a result of soil erosion and other factors, there is a considerable loss of organic matter in soil, while its content in soil plays a significant role for soil moisture. With the presumed increase in evapotranspiration and without a significant increase in precipitation, some of the most productive areas in the Czech Republic will be increasingly threatened by drought (Lobell and Field, 2007; Možný *et al.* 2009; Žalud *et al.*, 2009). Possible measures against the negative phenomena of temperature rise may be growing catch crops. Catch crops are crops grown between two main crops. Their importance in plant production is many-sided. Catch crops enrich the soil organic matter and capture nutrients. Another importance of catch crops lies in the use of rainfall in inter-seasonal period for biomass production and in limiting wind and water erosion compared with the soil without vegetation cover. Maintaining a sufficiently thick and continuous cover by catch crops restricts unproductive evaporation (Šlepetienė and Kinderienė, 2007; Rinnofner *et al.*, 2008; Chen *et al.*, 2010; Scalise *et al.*, 2015; Sparrow, 2015). Catch crops also act as an interrupter of cereal sequences in crop rotation. They also suppress weeds and reduce the spread and occurrence of diseases and pests (Murakami *et al.*, 2000; Caner and Tuncer, 2001; Romaneckas *et al.*, 2012). Growth and development of catch crops is limited by weather conditions (Satkus and Velykis, 2014; Constantin *et al.*, 2015). In general, the production capability of catch crops is negatively affected by water shortage during their sowing and growth (Arlauskienė and Maikštėnienė, 2006; Brant *et al.*, 2009). The second condition for successful cultivation of catch crops is temperature, which is related to the length of the growing season. Since the arrival of low temperatures, the growth of catch crops halts or is reduced to insignificant levels. Mündel *et al.* (2004) and Strašil and Hofbauer (2007) reported that *Carthamus tinctorius* is more demanding for moisture during the germination and before flowering and tolerates frosts down to -6°C. *Fagopyrum esculentum* is a thermophilic plant, sensitive to the lack of rainfall. It has a fast and aggressive start, but the first frost kills the plants (Vach *et al.*, 2005; Clark, 2008). *Phacelia tanacetifolia* is characterized by rapid growth and development, tolerates drought, and can be sown in drier locations. *Phacelia tanacetifolia* plants produce dense vegetation cover. *Sinapis alba* is undemanding to climatic and soil conditions. *Sinapis alba* has a quick initial start (Vach *et al.*, 2005; Vach, 2009; Brant *et al.*, 2011; Ramírez-García *et al.*, 2015). *Secale cereale v. multicaule* is a non-freezing catch crop with rich foliage, which grows well in adverse soil and climatic conditions (Pelikán *et al.*, 2013). Individual species of catch crops differ in their demand for water consumption and temperature. They also vary in their resistance to freezing and the initial rate of growth. For positive effect of catch crops, it is necessary to have a high coverage and appropriate biomass production (Haberle, 2006). Given the expected rise in temperature and expansion of drought in the most productive areas in the Czech Republic, it is necessary to examine the yield of individual species of catch crops in an area that belongs to the driest and warmest in the country. The Field Experimental Station Žabčice is located in such a risk area. The aim of this experiment is to evaluate the yield of several catch crops, such as *Sinapis alba*, *Phacelia tanacetifolia*, *Fagopyrum esculentum*, *Secale cereale v. Multicaule* and *Carthamus tinctorius.* It should determine the possible applicability of catch crops in areas with high average annual temperature and low precipitation totals.

MATERIALS AND METHODS

The small-plot field experiment was performed on clay-loam gleyic fluvisol at the Field Experimental Station in Žabčice, Southern Moravia, Czech Republic, within the period of 2006-2014. The content of nutrients in the soil: P – 140 mg kg^{-1}, K – 336 mg kg^{-1}, Ca – 5.513 mg kg^{-1} and pH/KCl – 7.1 in soil depth 0 – 0.3 m. In layer 0.3 – 0.6 m the values are P – 87 mg kg^{-1}, K – 227 mg kg^{-1}, Ca – 5.570 mg kg^{-1} and pH/KCl – 7.3. The average annual rainfall is 480 mm, while the average annual temperature is 9.2°C. That belongs to the driest and warmest areas in the Czech Republic. Table I shows the total annual rainfall and the average temperatures for the monitored years. The experiment was established by randomized block design with four replications, where the sizes of experimental plots were 15 m^2. The aboveground biomass of catch crops was monitored during the experiment. The experiment included five species of catch crops, namely *Sinapis alba*, *Phacelia tanacetifolia*, *Fagopyrum esculentum*, *Secale cereale v. multicaule*, and *Carthamus tinctorius*. The catch crops were established after harvesting winter wheat in August. Tillage and ploughing were carried out and before sowing catch crops pre-sowing soil preparation. The occurrence of weeds and volunteer wheat was very limited, that can be related to the soil processing due to the use of seeding machine. The seeding was done using a Plot seeders Wintersteiger. Crops sown in August were left in the field until March and when the following crop, spring barley, was sown. The crop sequence winter wheat – catch crop – spring barley took place in the same field and individual species of catch crops were sown on the same plots. To determine the yield of catch crops, a harvest of fresh aboveground biomass of catch crops took place in October, after about 70 days of vegetation. Table III summarizes the sowing schedule and sampling of aboveground biomass of catch crops. The harvest of fresh biomass of catch crops was conducted from 0.25 m^2 sampling plots in four replications for each species of catch crops. Afterwards, samples of biomass were dried in laboratory oven to a constant value of weight. Statistical analysis of the results was performed by Statistica CZ version 12, using analysis of variance and confidence interval (graphical presentations of significance are at the probability level of 95 %).

I: *Rainfall and temperature from Žabčice in the years 2006–2014*

Year	Month												Per year
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
	Rainfall (mm)												
2006	22.3	26.4	46.2	50.5	75.3	71.4	78.4	151.3	9.0	13.9	21.4	20.8	586.9
2008	15.7	10.4	32.9	29.3	53.5	19.6	49.9	55.9	46.1	27.3	22.1	31.1	393.8
2010	46.8	22.8	9.8	53.1	102.4	79.8	87.9	75.8	57.8	10.4	32.8	11.1	590.5
2012	27.2	7.4	2.4	19.8	21.4	101.2	64.6	43.0	40.2	49.2	19.4	35.6	431.4
2014	22.0	12.6	5.6	11.2	62.8	43.4	85.0	113.6	116.2	46.4	29.2	28.7	576.7
norm. 61–90	24.8	24.9	23.9	33.2	62.8	68.6	57.1	54.3	35.5	31.8	36.8	26.3	480.0
	Temperature (°C)												
2006	-6.1	-2.2	1.9	11.1	14.7	18.7	22.6	16.8	16.8	11.1	6.4	2.7	9.5
2008	1.8	2.6	4.8	10.1	15.4	19.8	20.4	20.0	14.3	9.8	6.5	1.8	10.6
2010	-3.9	-0.6	4.8	10.2	14.0	18.7	21.9	19.3	13.7	7.3	6.7	-3.9	9.0
2012	1.0	-3.4	7.0	10.8	16.9	19.8	21.4	21.1	16.2	9.4	6.5	-1.2	10.5
2014	1.1	2.7	8.5	11.8	14.5	18.8	21.5	17.9	15.6	11.5	7.5	2.4	11.2
norm. 61–90	-2.0	0.2	4.3	9.6	14.6	17.7	19.3	18.6	14.7	9.5	4.1	0.0	9.2

II: *Rainfall from sowing to sampling of catch crops divided into four parts in Žabčice*

Vegetation of catch crops from sowing to sampling	2006	2008	2010	2012	2014
	Rainfall (mm)				
First part	8.4	36.4	34.8	23.5	74.8
Second part	3.0	33.3	18.4	34.6	115.6
Third part	3.5	13.6	50.8	11.8	38.2
Fourth part	10.4	23.5	4.8	37.8	17.2
Total	25.3	106.8	108.8	107.7	245.8

III: *Date of sowing and sampling of aboveground mass of catch crops in 2006–2014 in Žabčice*

Date of operation	2006	2008	2010	2012	2014
Sowing of catch crops	30.8.	13.8.	12.8.	10.8.	12.8.
Sampling of aboveground mass of catch crops	31.10.	20.10.	19.10	22.10.	22.10.

IV: *Sowing rates of catch crops in 2006–2014 in Žabčice*

Catch crops	Sowing rates (kg ha^{-1})
Sinapis alba	25
Phacelia tanacetifolia	15
Fagopyrum esculentum	70
Secale cereale v. multicaule	150
Carthamus tinctorius	30

RESULTS AND DISCUSSION

The results have shown a statistically significant difference among different catch crops in biomass and even among years (Table V and Figures 1-8). *Sinapis alba*, *Phacelia tanacetifolia*, and *Fagopyrum esculentum* produced significantly higher dry matter yields than *Secale cereale v. multicaule* and *Carthamus tinctorius* (Figure 2). In general, the highest yields of catch crops were achieved in 2012 and the lowest in 2008. Individual reference years differed primarily in terms of rainfall conditions during the growing season of catch crops. In 2012, from sowing of catch crops to harvest of their aboveground mass, the measured rainfall was 107.72 mm and temperatures were higher than the long-term average. In 2012, the yield of catch crops ranged from 1.40 tons to 4.28 t ha^{-1}. The highest yields, over 2 t ha^{-1}, were recorded for *Sinapis alba*, *Fagopyrum esculentum*, and *Phacelia tanacetifolia*. The year 2012 was typical with sufficient amount and distribution of rainfall, both before and during the growing season of catch crops. However, among this group of catch crops and *Secale cereale v. multicaule* and *Carthamus tinctorius*, there was a statistically significant difference in the amount of biomass formed, probably because of the need for more water. During the 2010 growing season for catch crops, the recorded rainfall of 108.82 mm was almost the same as 2012. Again, the highest yields were reached for *Fagopyrum esculentum* (2.35 t ha^{-1}), *Phacelia tanacetifolia* (1.83 t ha^{-1}), and *Sinapis alba* (1.62 t ha^{-1}). a possible explanation may be the sufficient and especially optimal distribution of rainfall before sowing and during the germination of catch crops. However, in the second and fourth parts of the growing season of catch crops had, compared to other monitored years, less rainfall (Table II). This could be reflected in the overall yield of catch crops and especially the yield of *Carthamus tinctorius* and *Secale cereale v. multicaule*. In 2008, the total rainfall for the vegetation season of catch crops was similar to that in 2010 and 2012. However, compared to the other years, monitored throughout August, there was an unfavourable distribution of precipitation, as an (intense) precipitation was recorded on only three days. In general, this stress negatively affected all catch crops, but especially *Fagopyrum esculentum*, *Secale cereale v. multicaule*, and *Carthamus tinctorius*. This group of catch crops achieved statistically significantly lower yield than *Phacelia tanacetifolia* and *Sinapis alba*. The yield of *Secale cereale v. multicaule* was 0.42 t ha^{-1}, of *Fagopyrum esculentum* 0.30 t ha^{-1}, of *Carthamus tinctorius* 0.17 t ha^{-1}, of *Sinapis alba* 0.91 t ha^{-1}, and of *Phacelia tanacetifolia* 0.99 t ha^{-1}. The lowest rainfall during the growing season of catch crops was recorded in 2006. In 2006, there was a statistically significant difference between the yield of *Sinapis alba*, *Phacelia tanacetifolia* and *Secale cereale v. multicaule*, *Fagopyrum esculentum*, *Carthamus tinctorius*. In 2006, there was a significantly higher dry matter yield reached by *Sinapis alba* (2.26 t ha^{-1}) and *Phacelia tanacetifolia* (1.92 t ha^{-1}). Lack of rainfall has had an impact on the low yield of *Fagopyrum esculentum* (0.76 t ha^{-1}), *Carthamus tinctorius* (0.33 t ha^{-1}), and *Secale cereale v. multicaule* (0.26 t ha^{-1}). During the last part of the growing season of the catch crops, on some days the temperature dropped below 0°C, which had an effect of termination of the growth of *Fagopyrum esculentum*. In 2014, the statistical evaluation has shown no significant difference in the amount of biomass formed by catch crops. In that reporting year, there was a high above normal rainfall in August and September. When compared with other years, the highest yields of catch crops (between 1.13 t ha^{-1} and 1.98 t ha^{-1}) were not achieved despite sufficient water at the beginning of the growing season. The cause could have been that in October after an intense torrential rain, there was almost no rainfall recorded for a half month.

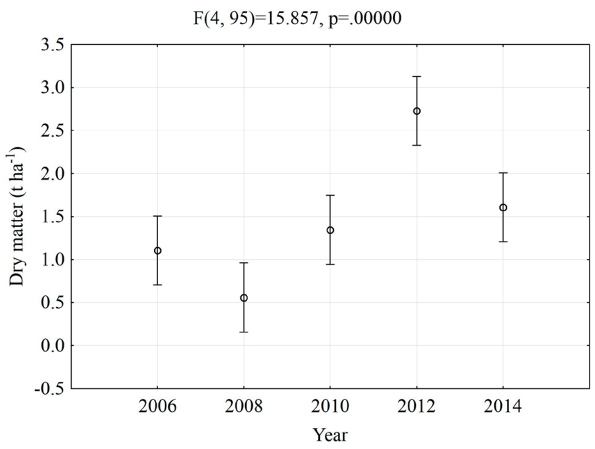
The results show that the highest yields and better stability of the production was observed in *Sinapis alba* and *Phacelia tanacetifolia*. In some years, *Fagopyrum esculentum* also generated higher yields. The group of catch crops that regularly produced lower biomass included *Secale cereale v. multicaule* and *Carthamus tinctorius*. Growth and development of catch crops depended on weather conditions in a given year, which is consistent with findings of Satkus and Velykis (2014) and Constantin *et al.* (2015). Catch crops were primarily limited by the available water supply in the soil and the amount and distribution of rainfall over their growing season. These results are consistent with the conclusions of Arlauskienė and Maikštėnienėskine (2006) and Brant *et al.* (2009). Temperature had a lesser impact on the catch crops yields. For example in *Fagopyrum esculentum*, the first autumn frost killed the plants (in 2006) and they stopped growing, as also stated by Vach *et al.* (2009). Therefore, *Fagopyrum esculentum* cannot completely fulfil one of the functions, namely soil coverage. Overall, the irregular distribution of torrential rainfall (2008) had a negative impact on catch crops, especially on *Fagopyrum esculentum*, *Carthamus tinctorius*, and *Secale cereale v. multicaule*. According to many authors, such as Žalud *et al.* (2009), we can expect an increased occurrence of torrential rain. It is therefore necessary to reckon with the fact that the expected unstable weather conditions during the growing season of catch crops will lead to a decline of their yields. Therefore catch crops which require more water for growth and development, such as *Carthamus tinctorius* and *Secale cereale v. multicaule*, do not fit to drier and warmer locations in the Czech Republic. Only in 2014 with a rainfall highly above normal, these catch crops almost matched the yields of those catch crops, which regularly reached the higher yields. That agrees with the claim by Mündel *et al.* (2004) and Strašil and Hofbauer (2007), that *Carthamus tinctorius* is more demanding for moisture during germination and growth season. In contrast, it goes against the claim by Pelikán *et al.* (2013) that the *Secale cereale v. multicaule* grows well even in unfavourable soil

V: *Analysis of variance for dry matter of catch crops*

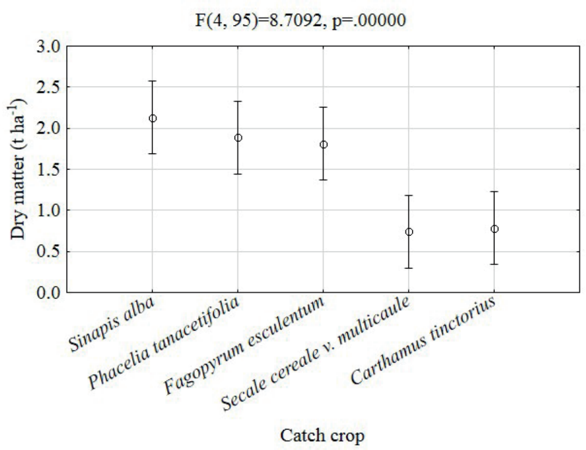
	source of variability	degrees of freedom	mean square	F value
Analysis of variance for dry matter of catch crops in 2006–2014				
2006–2014	year	4	12.92	15.86**
	error	95	0.81	
	catch crop	4	8.66	8.71**
	error	95	0.99	
	catch crop*year	16	1.28	4.34**
	error	75	0.30	
Analysis of variance for dry matter of catch crops in individual years				
2006	catch crop	4	3.46	10.07**
	error	15	0.34	
2008	catch crop	4	0.55	31.00**
	error	15	0.02	
2010	catch crop	4	2.87	8.95**
	error	15	0.32	
2012	catch crop	4	6.46	12.67**
	error	15	0.51	
2014	catch crop	4	0.47	1.61
		15	0.29	

** significance at the probability level of 99 %

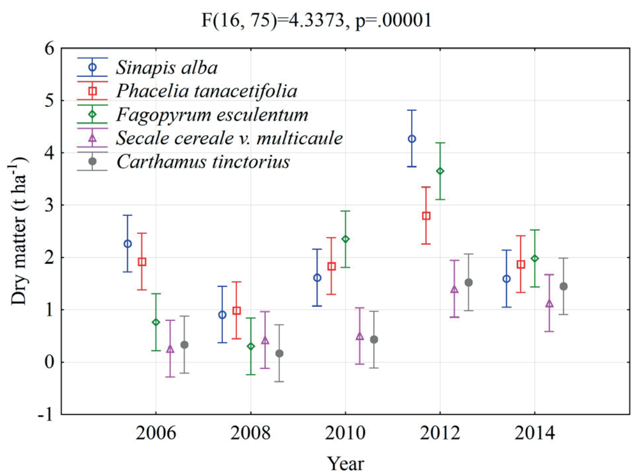
and climate conditions. In addition to *Secale cereale v. multicaule* and *Carthamus tinctorius*, the *Fagopyrum esculentum* too, is more sensitive to the lack of rainfall, as reported by Vach *et al.* (2005) and Clark (2008), but that was confirmed only in 2006. In other monitored years with an appropriate distribution of rainfall, *Fagopyrum esculentum* achieved the highest yields. Consistently highest yields were recorded for *Sinapis alba* and *Phacelia tanacetifolia*, which coincides with the conclusions of Brant *et al.* (2011). These catch crops were, according to the results, the least sensitive to different temperature and moisture conditions. *Sinapis alba* has a quick initial start as well as adequate coverage of soil and yield, which also coincides with Vach *et al.* (2009) and Ramírez-García *et al.* (2015). However, due to current narrow crop seeding with the predominance of *Brassica napus var. napus*, it is not appropriate to include *Sinapis alba*, which also belongs to the *Brassicaceae* family, as stated by Vach *et al.* (2009). Among the observed catch crops in areas with high average annual temperature and low rainfall totals, it is most suitable to grow *Phacelia tanacetifolia* and *Fagopyrum esculentum*. Both catch crops were characterized by rapid and aggressive start, as stated by Vach *et al.* (2005), Clark (2008) and Vach *et al.* (2009) and created a continuous vegetation growth with sufficient biomass. However, when *Fagopyrum esculentum* is hit by the first autumn frosts, it loses its ability to create sufficient vegetation growth. Continuously linked growth and sufficient biomass of catch crops is important in terms of meeting the basic objectives for their growing, such as limiting soil erosion, and so on, as stated by Haberle (2006). Given the expected rise in temperatures and occurrence of drought in the most productive areas of the Czech Republic in the future, *Phacelia tanacetifolia* and even *Fagopyrum esculentum* or a mixture thereof depending on the use of catch crops, may find their application.



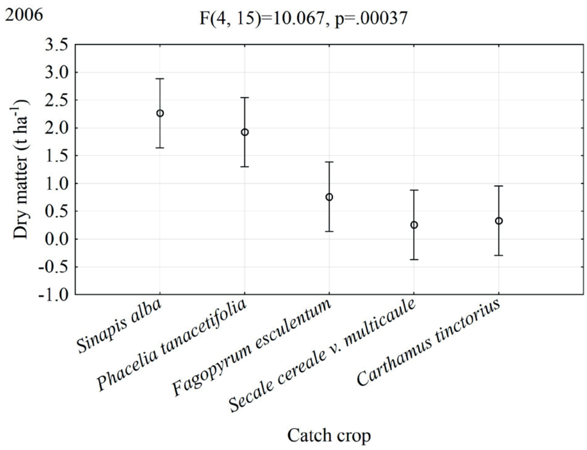
1: *Effect of the year on the average yield of dry matter of catch crops*



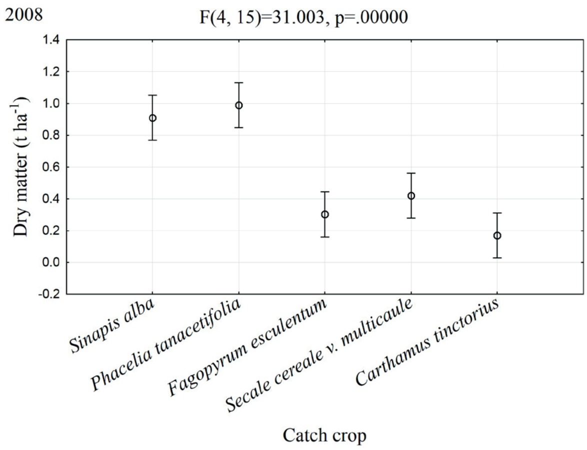
2: *Average yield of dry matter of species of catch crops for the whole period (2006–2014)*



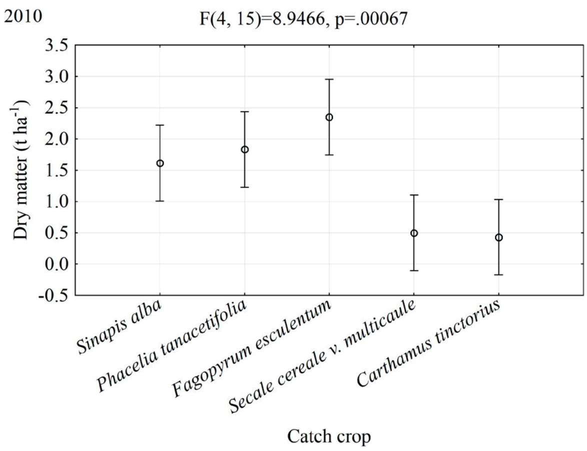
3: *Dry matter yield of species of catch crops in the individual years*



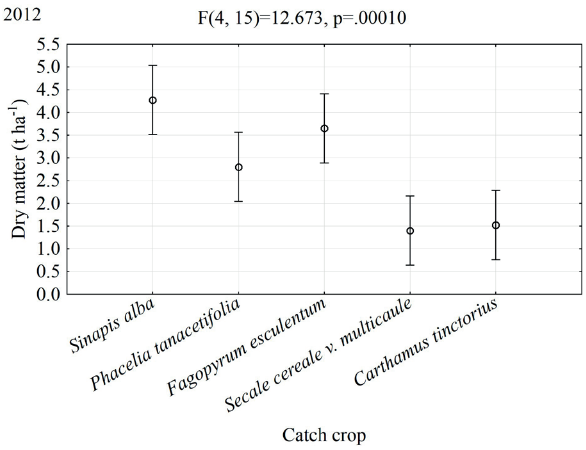
4: *Dry matter yield of species of catch crops in 2006*



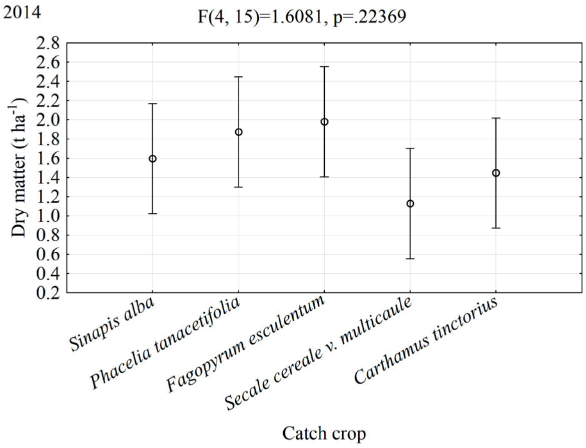
5: *Dry matter yield of species of catch crops in 2008*



6: *Dry matter yield of species of catch crops in 2010*



7: *Dry matter yield of species of catch crops in 2012*



8: *Dry matter yield of species of catch crops in 2014*

CONCLUSION

The aim of this study was to evaluate the yield of selected species of catch crops, including *Sinapis alba*, *Phacelia tanacetifolia*, *Fagopyrum esculentum*, *Secale cereale v. multicaule*, and *Carthamus tinctorius*, and to determine their potential applicability in areas with high average annual temperature and low precipitation totals. The yield results of catch crops are for the years between 2006 and 2014.

The obtained results show that the yield of catch crops is mainly dependent on a sufficient supply of water in the soil and the amount and appropriate distribution of precipitation throughout the growing season. In general, irregular, torrential rainfall negatively affects catch crops, mainly *Fagopyrum esculentum*, *Secale cereale v. multicaule*, and *Carthamus tinctorius*. *Secale cereale v. multicaule* and *Carthamus tinctorius* need for their growth and development more water and are therefore not suited to drier and warmer locations in the Czech Republic. Other monitored crops, namely *Sinapis alba* and *Phacelia tanacetifolia*, regularly reached the highest yields due to their lesser sensitivity to moisture and temperature conditions. In addition to these catch crops, *Fagopyrum esculentum* also had high yields. However, there is some risk of loss of sufficient coverage capability due to its sensitivity to the first autumn frosts. Due to the method of crop rotation in the Czech Republic, with a predominance of *Brassica napus var. napus*, it is inappropriate to include *Sinapis alba*. In areas with high average annual temperature and low rainfall totals, it is best to grow *Phacelia tanacetifolia* and even *Fagopyrum esculentum* or a mixture thereof, depending on the use of catch crops.

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Contact information

Martina Handlířová: martina.handlirova@mendelu.cz