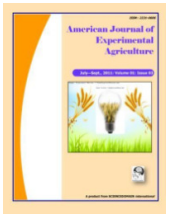

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Yielding Reliability of Legumes Grown as Stubble Catch Crop

Edward Wilczewski[1*] and Zbigniew Skinder[1]

[1]Department of Agrotechnology, Faculty of Agriculture and Biotechnology, UTP University of Science and Technology, 85-225 Bydgoszcz, Poland.

Authors' contributions

This work was carried out in collaboration between both authors. Author EW performed field study, developed the statistical analysis and wrote the first draft of the manuscript. Author ZS managed the field study. Both authors designed the field study, read and approved the final manuscript.

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ABSTRACT

Aims: The aim of the study was to determine the yielding reliability of serradella, field pea and yellow lupine, sown as stubble catch crop in August on a typical *Alfisol*.
Study Design: The randomized complete block design with four replications.
Place and Duration of Study: Field study was conducted in 2005–2009, at the Research Station in Mochełek near Bydgoszcz (17º51′ E; 53º13′ N) in Midwest Poland.
Methodology: The objects of the study were three leguminous plants: Serradella 'Igela', field pea 'Grapis' and yellow lupine 'Legat', grown as stubble catch crop on *Alfisols* formed of a sandy loam. The main studied features were yield of green matter and post harvest residues of plants. Moreover yield reliability in years for particular plants were calculated.
Results: The total yield of dry biomass of plants grown as stubble catch crop ranged from 1.76 Mg·ha^{-1} in 2005, with shortage of rainfall, to 3.65 Mg·ha^{-1} in 2006, which was characterized by a high rainfall in August and high temperatures in September. The total dry matter yield of field pea and yellow lupine was significantly higher than from serradella. The highest aboveground dry matter yield was obtained from pea, and the lowest from serradella. Proportion of post-harvest residues in the total dry weight yield usually amounted to 30-40%. Yellow lupine produced a significantly higher average from 5 years yield of post-harvest residues than field pea and

**Corresponding author: E-mail:* edward@utp.edu.pl;

serradella.
Conclusion: Serradella, field pea and yellow lupine sown as stubble catch crop within 3-12 August are characterized by a high reliability of dry matter yield, from approximately 80.5% (yellow lupine) to 83.8% (field pea). Serradella matched the other plants in terms of the yield reliability, but the yield of green mass of the plants was significantly lower than that of pea and lupine.

Keywords: Catch crop; field pea; reliability; serradella; yellow lupin; yielding.

1. INTRODUCTION

The value of legumes in shaping the physical, biological and chemical properties of soil is well-known [1-3]. These plants used as green manure contribute to the improvement of the enzymatic activity of the soil, increase the content of soil available forms of nitrogen and improve the yield of plants grown in the succeeding year [2,4]. Despite this, the proportion of legumes in crop structure in Poland is very low [5]. This is due to the relatively low demand for green fodder for animals. At the current stock of cattle, nutritional requirements of this group of animals are covered mainly using feeds produced on permanent grassland. In addition, farmers are reluctant to grow these plants as catch crops intended for green manure. This is due to the conviction of not reliable yielding of these plants cultivated as catch crops sown in August.

To achieve high yields, these plants are recommended as stubble catch crop sown in July [6]. Currently, such sowing time of stubble catch crop in Central and Eastern Europe is mostly impossible because of the late harvest time of cereals, which are followed by these crops.

However, studies published in the past 20 years indicate that some legumes can produce satisfactory yields even at sowing approximately August the 10th - 20th [7]. The condition of the crop to go is mainly adequate supply of water in the soil during the planting and good thermal conditions in September, enabling fast growth of biomass [8-10]. In the study by Rinnofner et al. [9] dry matter yield of legumes mixture (field pea + common vetch + chickling vetch) was 3.46 Mg·ha^{-1} in the year with favorable rainfall patterns and only 1.0 Mg·ha^{-1} in the year characterized by a substantial deficiency of rainfall throughout the growth period of plants grown as the catch crop. In a study by Zaniewicz-Bajkowska et al. [11], dry matter yield of faba bean and serradella sown as the catch crop on July the 21st amounted to 5.4 Mg·ha^{-1} and 2.9 Mg·ha^{-1} respectively. In this yield 135 and 79 kg·ha^{-1} N, respectively, was accumulated. The reduction in dry matter yield of serradella and faba bean resulting from sowing delay from July the 21st to August the 18th amounted to 27.6 and 55.6%. The cited studies indicate that the sowing time is an important factor for the yield of legumes grown as the catch crop, but its delay until mid-August does not exclude the possibility of obtaining the yield of the importance as fertilizer for plants grown in the following year. More important is the amount of rainfall during the planting, conditioning the proper course of seed germination.

The aim of the study was to determine the yielding reliability of serradella, field pea and yellow lupine, sown in stubble catch crop in August on a typical *Alfisol*.

2. MATERIALS AND METHODS

2.1 Experimental Design and Conditions

The field study was conducted in 2005 – 2009, at the Research Station in Mochełek near Bydgoszcz (17º51′ E; 53º13′ N) in Midwest Poland. It was a continuation of the study carried out in 2002-2004, published in the paper “Value of selected papilionaceous crops grown in stubble intercrop on light soil. Part I. Biomass yield and plant health status” [12]. The objects of the study were three leguminous plants: Serradella 'Igela', field pea 'Grapis' and yellow lupine 'Legat'. The randomized complete block design with four replications was used. The area of plots for harvest was 27 m^2. Previous crop for plants grown as catch crops was spring barley. The field experiment was performed in *Alfisols* [13], formed of sandy loam, of IVa quality class. The soil had slightly acidic reaction (pH in 1M KCl 6.2) and contained very high amount of available phosphorus and potassium (107 and 325 mg of P and K in kg of dry soil, respectively). Content of total nitrogen and organic carbon in the soil amounted to 660 and 7200 mg in kg of dry soil respectively. Field water capacity of soil in the study area ranged from 215 to 270 mm at the depth from 0 to 100 cm [14].

The pluviotermic conditions during the period of study was determined on the basis of Sielianinov hydrothermal coefficient [15]:

$$\text{Sielianinov coefficient (k)} = \frac{P\ 10}{\sum t} \qquad (1)$$

Where P is total precipitation in the given period [mm], Σt – total of average daily air temperatures from that period [ºC].

2.2 Cultivation Conditions and the Course of Experiment

After harvest of spring barley mineral fertilizers were spread (26 kg·ha^{-1} P and 66 kg·ha^{-1} K) and soil disking was performed to mix the stubble and fertilizers with the soil. Subsequently plowing to the depth of about 12 cm was performed. Before sowing the soil was cultivated using a cultivator with a crumbler roller.

The sowing parameters were as follows:

- Sowing time: 3-12 August (Table 1);
- Row-space: 12.5 cm;
- Sowing depth: Serradella – 2-3 cm; field pea – 4-5cm; yellow lupine – 3-4cm;
- Sowing rates [kg·ha^{-1}]: serradella – 60; field pea – 150; yellow lupine – 140.

The number of plant per m^2 was determined on each experimental plot 3 weeks after sowing. In the second part of October, after 70-79 days after sowing, the yield of green matter of plants was determined.

Table 1. Parameters concerning catch crops sowing and harvesting

Year	Sowing time	Harvest time	Growth day
2005	04.08	20.10	78
2006	11.08	19.10	70
2007	03.08	17.10	76
2008	12.08	21.10	71
2009	11.08	28.10	79

Dry weight of aboveground biomass was determined based on 1kg of green mass samples taken from each plot. In order to determine the yield of fresh and dry weight of the post-harvest residues, soil monoliths measuring 25·25·25 cm were collected from each plot and screened through a sieve with a mesh size of 4 mm. Subsequently, the samples were rinsed with tap water. Then after initial drying the samples on absorbent paper they were weighed (fresh matter yield), dried in an oven at 50ºC and reweighed (dry matter yield).

2.3 Statistical Analysis

The results were statistically analyzed using analysis of variance, which was made with a computer program AWAR, developed in the Department of Agrometeorology and Applied Informatics, Institute of Soil Science and Plant Cultivation in Pulawy [16]. The analysis was conducted for the randomized block design. The significance of differences was determined using Tukey's half-interval at the significance level α = 0.05. To estimate the relation between the total precipitation in July and August and dry matter yield of plants regression analysis was carried out using Statistica for Windows version 10 software.

Yield reliability coefficients (Rc) were calculated using the formula by Rudnicki and Wasilewski [17]:

$$\mathrm{Rc} = \frac{\bar{x}}{\bar{x}+s} \cdot 100 \qquad (2)$$

Where $\bar{x}$ is the average yield of the years of research, while the s is standard deviation of yield in those years.

3. RESULTS AND DISCUSSION

3.1 Weather Conditions in the Study Region

Weather conditions in the area of research were very different in particular years. Most adverse conditions occurred in 2005, in which precipitation totals in all months of the catch crop growth period were significantly lower than the long-term average total for this region (Table 2). Also in the month preceding the sowing of seeds (July) precipitation accounted for only half of the total typical of this month. Due to the shortage of water available for plants also high temperatures in September were undesirable factor, which enhanced the negative effects of rainfall deficit.

In 2006, the supply of plants in rainwater was better suited to the growing of plants grown in stubble catch crop. Very high rainfall in August and average in September favored dynamic growth of plants. It was also possible due to the relatively high air temperatures in this month.

In subsequent years, the plants were well supplied with rainwater in July (2007 and 2009) or in July and August (2008). However, relatively low air temperatures were observed in September (2007 and 2008) and October (2007 and 2009).

Evaluation of pluviotermic conditions made based on the Sielianinov hydrothermal coefficient [15] showed that throughout the five-year study period there was not a single season free of drought during the catch crop growth period (Table 3).

However, as seen from the other studies conducted in this area, for yielding of plants grown as stubble catch crop most important is to supply the plant with water during July-August. With total rainfall in July and/or August of at least 100 mm high yields of dry matter can be achieved, even in drought conditions during September and October [18].

Thus, the conditions occurring in the period 2006-2009 can be considered favorable for the cultivation of stubble catch crop. In each of these years, at least in one of those months Sielianinov coefficient was above 1.

3.2 Plant Density after Emergence and Yield of Dry Matter

Plant density after emergence varied between years (Table 4). It was the lowest in 2005, in which a drought occurred both in July and in August. The highest plant density after emergence was found in 2008, in which the rainfall in July was average and in August very high. Particular species grown as stubble catch crop unevenly responded to environmental conditions during germination and emergence. Coefficient of variation of plant density after emergence in the years of the study was the lowest for the pea and the highest for serradella. The different response of individual species may be due to different depths of sowing. The seeds of pea were sown deepest, therefore they can make better use of water accumulated in the soil than the other plants.

Table 2. Mean air temperature and total rainfall, in period from July to October

Years	July	August	September	October	Mean/total VII X
			Mean air temperature [°C]		
2005	19.4	16.3	14.8	8.7	14.8
2006	22.4	16.6	15.2	9.6	16.0
2007	18.0	17.8	12.4	6.9	13.8
2008	19.2	17.8	12.4	8.4	14.5
2009	18.6	18.2	13.7	6.3	14.2
Mean 2005-2009	19.5	17.3	13.7	8.0	14.7
Mean 1949-2009	18.0	17.4	13.2	8.2	14.2
			Total monthly rainfall [mm]		
2005	33.6	43.4	17.8	15.1	109.9
2006	24.2	129.0	40.6	12.1	205.9
2007	104.7	42.1	37.6	19.9	204.3
2008	58.7	95.5	20.2	80.0	254.4
2009	118.0	17.6	34.4	66.2	236.2
Mean 2005-2009	67.8	65.5	30.1	38.7	202.1
Mean 1949-2009	70.8	52.0	41.0	32.7	196.5

Table 3. Ploviotermic conditions in period from July to October

Year	July	August	September	October
2005	Very dry*	Dry	Extremely dry	Very dry
2006	Extremely dry	Very wet	Dry	Very dry
2007	Rather wet	Dry	Rather dry	Dry
2008	Dry	Rather wet	Very dry	Extremely wet
2009	Wet	Extremely dry	Dry	Extremely wet
Mean 2005-2009	Rather dry	Rather dry	Dry	Rather wet

**Ploviotermic conditions based on Sielianinov coefficient (k): extremely dry – k≤0.4; very dry – 0.4>k≤0.7; dry – 0.7>k≤1.0; rather dry 1.0>k≤1.3; optimal – 1.3>k≤1.6; rather wet – 1.6>k≤2.0); wet – 2.0>k≤2.5; very wet – 2.5>k≤3.0; extremely wet – k>3.0 [15]*

Table 4. Plant density after emergence [no·m^{-2}]

Year	Serradella	Field pea	Yellow lupine	Mean
2005	121	78	48	82
2006	177	96	100	124
2007	269	76	73	139
2008	328	123	81	177
2009	284	80	55	140
Mean	236	91	71	133
Variation coefficient [%]	35.8	21.8	29.1	25.8

Yields of individual species grown as stubble catch crop was varied in the years of the study (Table 5). The yield of green matter of plants grown as stubble catch crop ranged from 0.66 - 0.87 Mg·ha^{-1} dry mass in 2005, characterized by the shortage of rainfall in the whole growth period, to 1.92 - 2.60 Mg·ha^{-1} in 2006, characterized by high rainfall in August and relatively high temperatures in September. The highest yields of green matter were obtained from pea, and the lowest of serradella. Green matter yield of yellow lupine was in 2 of the 5 years higher than in serradella and only in 1 out of 5 years it was significantly lower than in pea. The average of 5 years of research post-harvest crop residues of lupine was significantly higher than pea and serradella which in 4 out of 5 years of research produced a similar mass of post-harvest residues. The total dry matter yield of pea and yellow lupine was significantly higher than that obtained from serradella. The proportion of post-harvest residues in total dry weight yield was most commonly 30-40%. Extremely high proportion of these parts of plants in the yield was obtained in the dry year 2005, when it amounted to 57.4%. This was due to the very low yield of aboveground biomass in this year.

The total dry matter yield of field pea was 16.4 and 30.0% lower compared to the tansy phacelia and oilseed radish grown under the same conditions [10]. In the case of yellow lupine the difference amounted to 19.3 and 32.5% respectively.

In the eight-year study period, a high yielding reliability of legumes grown as stubble catch crop was stated (Table 6). The differences between the studied species were 3.2 - 3.6 percentage points for the aboveground dry matter yield and only 1.3 - 3.3 percentage points for total dry matter.

Table 5. Dry matter yield of plants grown as catch crops [Mg·ha^{-1}]

Year	Plant			Means
	Serradella	Field pea	Yellow lupine	
Green matter				
2005	0.66 b	0.87 a	0.70 ab	0.74
2006	1.92 b	2.60 a	2.58 a	2.37
2007	1.49 b	2.44 a	1.73 b	1.89
2008	1.37 b	2.58 a	1.79 ab	1.91
2009	1.03 b	2.41 a	2.18 a	1.88
2005-2009	1.30 c	2.18 a	1.80 b	1.76
Post-harvest residue				
2005	0.89 a	1.06 a	1.09 a	1.01
2006	1.21 ab	1.13 b	1.52 a	1.29
2007	1.04 a	0.97 a	1.19 a	1.07
2008	1.31 a	1.14 b	1.40 a	1.29
2009	0.62 b	0.63 b	1.12 a	0.79
2005-2009	1.01 b	0.99 b	1.26 a	1.09
Total dry matter				
2005	1.56 a	1.93 a	1.79 a	1.76
2006	3.12 b	3.73 ab	4.10 a	3.65
2007	2.52 a	3.41 a	2.91 a	2.95
2008	2.68 b	3.72 a	3.19 ab	3.20
2009	1.65 b	3.04 a	3.31 a	2.67
2005-2009	2.31 b	3.17 a	3.06 a	2.85

 # – means marked with different letters in lines differ significantly at α = 0.05

Previous research on this subject indicates that the studied plants, especially serradella have unreliable yielding due to the delayed sowing [6]. In our study, the reliability coefficient of serradella yield was as high as for the peas. However, this high reliability referred to yield lower by 27% compared to the peas.

Yielding of crops grown as stubble catch crop depends mainly on rainfall in July and August as well as on the air temperature in September and October [8,10,19]. Regression analysis shows that the optimum amount of precipitation in July and August for field pea in typical Alfisols soil condition is 154 mm. It allows the dry biomass yield of 3.36 Mg·ha^{-1} (including 2.44 Mg·ha^{-1} green matter) (Table 7). The highest green matter yield of yellow lupine can be achieved with total rainfall of 142 mm during this period. The analysis showed that field pea and yellow lupine sown in stubble catch crop within 3-12 of August are characterized by a high reliability and satisfactory yielding. Serradella definitely did not match these plants in terms of the yield level.

Table 6. Yielding reliability of dry matter yield in years of the study 2002-2009 [%]

Part of plant	Plant		
	Serradella	Field pea	Yellow lupine
Green matter	77.1	77.5	73.9
Post-harvest residue	77.8	79.5	78.9
Total dry matter	81.8	83.8	80.5

Table 7. Regression equations for dry matter yield of catch crops depending on rainfall totals in the period from 1 July to 31 August (n=8)

Catch crop		Regression equation#	R^2	p	Optimal rainfall [mm]	Estimated yield at optimal rainfall [Mg·ha^{-1}]
Green matter	Serradella		0.54	n.s.*		
	Field pea	$y=-0.2632x^2+80.9x-3781$	0.71	0.044	154	2.44
	Yellow lupine	$y=-0.3249x^2+92.3x-4548$	0.73	0.037	142	2.01
Total dry mass	Serradella		0.50	n.s.		
	Field pea	$y=-0.253x^2+78x-2646$	0.74	0.036	154	3.36
	Yellow lupine		0.60	n.s.		

*# - regression equation calculated based on data from years 2002-2009, * - n.s. - not significant*

5. CONCLUSION

Serradella, field pea and yellow lupine sown as stubble catch crop within 3-12 August showed a high reliability of dry matter yield, ranging from 80.5% (yellow lupine) to 83.8% (field pea). Serradella matched the other plants in terms of the yield reliability, but the yield of green matter of the plants was significantly lower than that of pea and lupine.

The study showed a high yield potential of pea and yellow lupine. The best conditions to obtain a high yield of dry weight of these plants occur in the years in which the rainfall in July and/or August amounts to 142 mm for yellow lupine and 154 mm for field pea.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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