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THE EFFECT OF COVERS APPLICATION IN THE BROAD BEAN (*VICIA FABA* SSP. MAJOR) CULTIVATION

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The experiment was carried out in 2007–2009. The investigated factors were: the kind of covers – without covering (control object), perforated foil with 100 holes per 1m^2, polypropylene fibre weighing 17 g m^{-2} and broad beans cultivars – 'Windsor Biały', 'Bizon' and 'Bachus'. Broad bean seeds were sown at the beginning of the second 10-days of April, at a spacing of 50 × 10 cm. Directly after, sowing field was covered by covers, which were left for 3 weeks. Broad bean was harvested in the stage of milky maturity of seeds. Before the harvest, the number of pods per plant was determined. During the harvest, the weight of pods and the yield of fresh seed were determined and productivity of seed from the weight of pods was calculated. Biometric parameters of pods and seeds i.e. length of pods, the number of seeds in the pod and length, width and thickness of seed was performed. It was found that the broad bean covering contributed to increase yield and improvement of the biometric parameters of pods and seeds compared to the control object without covering. The highest yield of pods and seeds produced cv 'Bizon'. The best yield was obtained from plants covered by polypropylene fibre. The seeds of cultivated cultivars were characterized by similar parameters. Polypropylene fibre covering favoured formation of pods and seeds in the pods but did not cause changes in the seeds parameters.

Keywords: broad bean, yield of seed, quality of yield, covers

Production of vegetables for early harvest has particular importance because of the seasonality of the supply and consumption of fresh vegetables. The supply of fresh vegetables in early spring largely reduces the seasonality of consumption. In the first half of the year it does not exceed 30%, because only in the second half of the year there appear basic kinds of vegetables. The success of vegetable cultivation in the field for early harvest depends on many factors, among which important roles have agronomic factors (Rekowska, 2007). One of them is the direct covering of plants grown in the field, which ensures the maintenance of higher soil and air temperature, higher humidity, and protection of plants from frost (Gordon et al., 2008; Błażewicz-Woźniak et al., 2014). Numerous studies indicate that the use of flat covers in the vegetable cultivation contributes to the acceleration of harvest by about few days, increases the quantity and quality of vegetable yield, particularly grown for early harvest (Łabuda and Baran, 2005; Siwek and Libik, 2005; Biesiada, 2008; Kosterna, 2014; Rosa, 2014). The effect of covering application depends on the kind of cover, weather conditions and the cultivated plant (Błażewicz-Woźniak, 2009; Koudela and Petříková, 2009).

Immature seeds of broad beans are appreciated primarily as a source of easily digestible protein, carbohydrates, vitamins and minerals (Kulka and Grzesiuk, 1978). Broad bean is a plant that requires early sowing, the term depending on the climate region occurs from the end of March to the second 10-days of April. Early sowing ensures good emergence through a large resource of moisture in the soil. Delay in sowing due to weather conditions causes a significant reduction in seed yield compared to the achieved from the early sowing.

The study aim was to determine the effect of perforated foil and polypropylene fibre covering on the yield and biometric parameters of pods and seeds in the cultivation of three broad bean cultivars.

Material and methods

The experiment was carried out in 2007–2009 in central-eastern Poland (52° 03' N, 22° 33 'E). According to the international system of FAO classification, the soil was classified as Luvisol (WRB, 2015). Soil was characterized by a humus level of 30–40 cm and average organic carbon content amounted to 2.1%, the value of pH determined in H_2O 5.73. The total contents of macroelements in mg l^{-1} amounted to 11 mg NH_4N, 6 mg NO_3N, 73 mg P_2O_5, 65 mg K_2O, 380 mg Ca, 40 mg Mg.

The study took into account the following factors: kind of cover – control without cover, covering with perforated foil (100 holes per 1 m^2, ∅ 10 mm), covering with polypropylene fibre (PP 17 g m^{-2}), broad bean cultivars – 'Windsor Biały', 'Bizon', 'Bachus'. The experiment was established as a split-block design with three replicates. The area of one plot for harvest was 15 m^2.

The field for cultivation of the broad bean was prepared in the first 10 days of April in accordance with the principles

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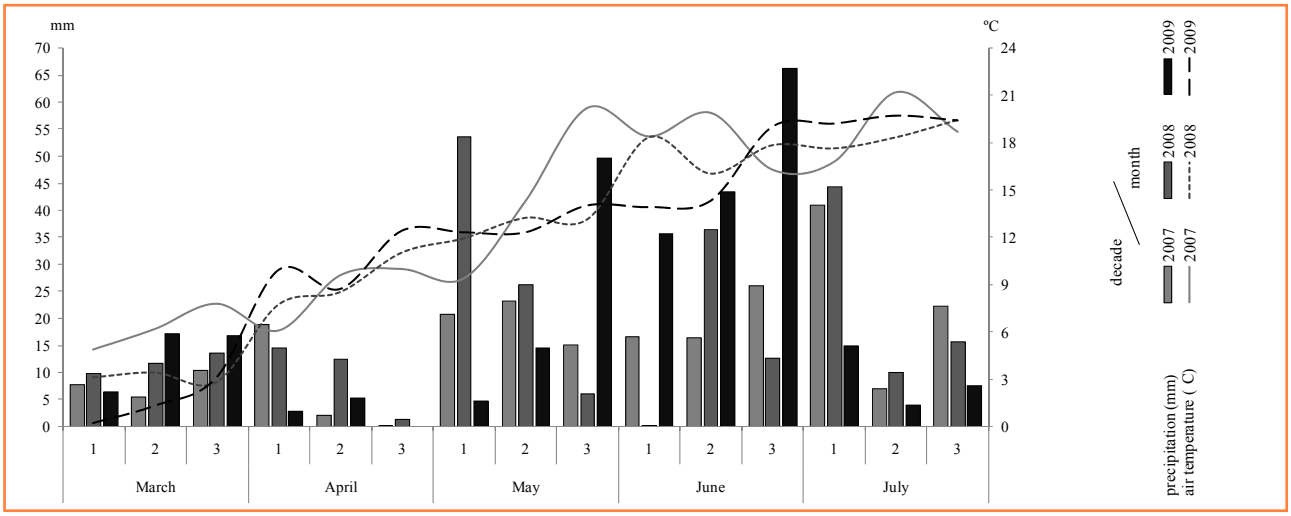

Figure 1 Weather conditions in the period of study

of proper agricultural technology for this species. Mineral fertilizers were applied in order to complement the nutrient content in the soil to the optimum level for this plant ≥30 mg N dm^{-3}, 70 mg P dm^{-3}, 150 mg K dmm^{-3}, 60 mg Mg dm^{-3}, 1500 mg Ca dm^{-3} (Sady, 2000). Broad bean seeds were sown at the beginning of second 10 days of April, at a spacing of 50 × 10 cm. Directly after, sowing on the suitable combination of covers was applied, which were removed after 3 weeks. Care treatments have included weed control and plant protection against pests and diseases in accordance with the recommendations of the Programme for the Protection of Vegetables.

Broad bean was harvested at the beginning of first 10 days of July, in the stage of milky maturity of seeds. Before the harvest, there was counted the number of pods per plant. During the harvest, the yield of pods and seeds and biological productivity of the yield were determined. The biological productivity was a difference in the weight of pods and seeds' weight, expressed as a percentage. For the evaluation of biometric features from the each combination there were taken samples 100 pods and 100 seeds. The number of seeds in a pod was calculated, the length of pod, the thickness of the seed and their length and width were measured.

The results were statistically analysed by ANOVA. The significance of differences was determined by the Tukey test at the significance level of $P \leq 0.05$. All the calculations were performed in STATISTICA®, version 12.0 and MS Excel.

Legumes have a high diversity in yield level depending on weather conditions, mainly distribution and total precipitation and air temperature during flowering and ripening (Szyrmer et al., 1992). High air temperature negatively affects growth and yield of crops, while cold weather during flowering reduces the ability of ovary development, which impacts on limitation of the number of pods per plant (Graham and Ramalli, 1997).

Weather conditions during the growing season of broad bean were varied and not always favoured the growth and development (Figure 1). In April, immediately after seeds sowing, when weather conditions determined the seed germination and initial growth of plants, in 2007 and 2008 the amount of precipitation was similar to the long-term average for this month (29.4 mm) and significantly higher than in 2009. A very small amount of precipitation in April 2009 (only 8.1 mm) was the cause of the poor plant emergence. In June, during the pods formation, in 2007 and 2008, there was noted a lower amount of precipitation (69.3 mm) compared to the long-term average (respectively by 10.0 and 20.0 mm). In 2009, the amount of precipitation in June exceeded the long-term average by more than double. In all the years of study the period of broad bean cultivation was characterised by thermal conditions similar to the long-term average for these months.

Results and discussion

Irrespective of the examined experimental factors, there were found large differences in the yield of broad beans in the years of study (Table 1). The highest and lowest yield of pods and seeds was obtained in 2008 and 2009, respectively. The yield from 2009 was also characterised by the lowest biological productivity. The worsened weather conditions in 2007 did not favour pods formation. The highest length was characterised in pods from 2009. In the all years of study, broad bean pods had similar number of seeds; however, parameters determining the biometric features of seeds were the lowest in 2007.

There was found a significant effect of covering on the yield of cultivated broad bean cultivars (Table 2). The highest yield of pods and seeds was obtained from the plants covered with polypropylene fibre. It was significantly higher, by 19% and 28% respectively compared to the one achieved at perforated foil covering and by 33% and 40% compared to control without covering. An increase of green beans yield after polypropylene fibre covering was found by Łabuda and Baran (2005). Also Biesiada and Kędra (2012) after application of polypropylene fibre cover, there was found an increase in the yield of dill cultivated for early harvest by 86.8%. In the authors' own research in the uncovered cultivation the highest yield of pods was obtained from cv 'Windsor Biały'. Irrespective of the kind of cover, the highest yield of pods produced cv 'Bizon'.

Table 1 Yield and biometric features of broad bean pods and seeds in the years of study

Years	Pod yield (t ha^{-1})	Seed yield (t ha^{-1})	Biological productivity of yield (%)
2007	13.14 b*	3.63 b	27.78
2008	14.90 c	4.88 c	32.04
2009	7.13 a	1.76 a	22.21
Mean	11.70	3.42	27.51
NIR$_{0.05}$	1.05	0.41	-
Years	**Pod number per plant (no.)**	**Pod length (cm)**	**Seed number in pod (no.)**
2007	4.9 a	12.8 a	3.7 a
2008	5.4 b	13.5 b	3.6 a
2009	5.4 b	14.8 c	3.6 a
Mean	5.3	13.7	3.6
NIR$_{0.05}$	0.2	0.4	n.i.
Years	**Seed length (mm)**	**Seed width (mm)**	**Seed thickness (mm)**
2007	21.9 a	16.1 a	9.4 a
2008	24.3 b	18.7 b	11.4 b
2009	24.2 b	18.7 b	9.5 a
Mean	23.4	17.8	10.1
NIR$_{0.05}$	1.2	0.5	1.0

* Values followed by the same letters in columns do not differ significantly at $P \leq 0.05$

Table 2 Broad bean yield (mean for 2007–2009)

Kind of cover	Cultivar			Mean
	'Windsor Biały'	**'Bizon'**	**'Bachus'**	
Pod yield (t ha^{-1})				
Control without cover	10.06 b*	9.61 ab	8.87 a	9.51 A
Perforated foil	10.87 a	12.73 b	10.85 a	11.48 B
Polypropylene fibre	13.81 a	15.87 b	12.83 a	14.17 C
Mean	11.58 ab	12.73 b	10.85 a	11.72
NIR$_{0.05}$	kind of cover = 1.05; cultivar = 0.96; kind of cover *x* cultivar = 1.15			
Seed yield (t ha^{-1})				
Control without cover	2.73 a	2.82 a	2.48 a	2.68 A
Perforated foil	2.85 a	3.77 b	2.89 a	3.17 B
Polypropylene fibre	4.40 b	5.03 c	3.86 a	4.43 C
Mean	3.32 a	3.88 b	3.07 a	3.42
NIR$_{0.05}$	kind of cover = 0.41; cultivar = 0.42; kind of cover *x* cultivar = 0.49			
Biological productivity of yield (%)				
Control without cover	24.50	27.09	24.72	25.44
Perforated foil	25.96	29.57	25.96	27.16
Polypropylene fibre	31.05	31.15	27.58	29.93
Mean	27.17	29.27	26.09	27.51

* Values followed by the same small letters in rows and capital letters in columns do not differ significantly at $P \leq 0.05$

Table 3 Biometric parameters of pods

Kind of cover	Cultivar			Mean
	'Windsor Biały'	'Bizon'	'Bachus'	
Number of pods per plant (no.)				
Control without cover	4.6 ab*	3.4 a	4.7 b	4.3 A
Perforated foil	5.4 b	5.0 a	5.8 c	5.4 B
Polypropylene fibre	5.7 a	7.0 b	5.8 a	6.2 C
Mean	5.2 a	5.2 a	5.4 a	5.27
$NIR_{0.05}$	kind of cover = 0.20; cultivar = n.s.; kind of cover *x* cultivar = 0.28			
Number of seeds in pod (no.)				
Control without cover	3.9 b	3.6 a	3.7 a	3.7 B
Perforated foil	3.4 a	3.4 a	3.7 b	3.5 A
Polypropylene fibre	3.9 b	3.7 a	3.6 a	3.7 B
Mean	3.7 a	3.6 a	3.6 a	3.6
$NIR_{0.05}$	kind of cover = 0.12; cultivar = n.s.; kind of cover *x* cultivar = 0.18			
Pod length (cm)				
Control without cover	13.6 a	14.2 b	13.1 a	13.7 AB
Perforated foil	12.8 a	13.2 a	14.1 b	13.4 A
Polypropylene fibre	13.4 a	14.5 b	14.1 b	14.0 B
Mean	13.3 a	14.0 b	13.8 a	13.7
$NIR_{0.05}$	kind of cover = 0.39; cultivar = 0.43; kind of cover *x* cultivar = 0.55			

* Explanations as in table 2

Table 4 Biometric parameters of seeds

Kind of cover	Cultivar			Mean
	'Windsor Biały'	'Bizon'	'Bachus'	
Seed length (mm)				
Control without cover	22.9 a*	24.5 a	22.8 a	23.4 A
Perforated foil	23.1 a	24.0 a	23.2 a	23.5 A
Polypropylene fibre	22.8 a	24.0 a	23.5 a	23.4 A
Mean	22.9 a	24.2 b	23.2 a	23.4
$NIR_{0.05}$	kind of cover = n.s.; cultivar = 0.6; kind of cover *x* cultivar = n.s.			
Seed width (mm)				
Control without cover	16.9 a	17.4 a	17.4 a	17.2 A
Perforated foil	18.9 c	17.9 b	17.3 a	18.0 B
Polypropylene fibre	17.9 a	18.1 a	18.5 a	18.2 B
Mean	17.9 a	17.8 a	17.7 a	17.8
$NIR_{0.05}$	kind of cover = 0.5; cultivar = n.s.; kind of cover *x* cultivar = 0.6			
Seed thickness (mm)				
Control without cover	9.8 a	10.5 a	10.7 a	10.3 A
Perforated foil	10.1 a	10.2 a	9.3 a	9.9 A
Polypropylene fibre	9.7 a	10.3 a	10.2 a	10.1 A
Mean	9.9 a	10.3 a	10.1 a	10.1
$NIR_{0.05}$	kind of cover = n.s.; cultivar = n.s.; kind of cover *x* cultivar = n.s.			

* Explanations as in table 2

Among the cultivated cultivars, the highest yield of seeds was characteristic for broad bean cv 'Bizon'. In the uncovered cultivation, the yield of seeds of investigated cultivars was similar and ranged from 2.48 t ha^{-1} for cv 'Bachus' to 2.82 t ha^{-1} for cv 'Bizon'. After application of perforated foil, the yield of seeds cv 'Bizon' was higher by 24.5% compared to the yield of seeds cv 'Windsor Biały' and by 23.3% compared to cv 'Bachus'. After polypropylene fibre application, it was higher by 12.5% and 23.3%, respectively. Among cultivated cultivars the highest biological productivity of yield was characteristic for broad bean cv 'Bizon'. The highest biological productivity of yield was obtained after polypropylene fibre covering.

Covers applied in the cultivation of broad beans significantly differentiated the number of pods per plant, their length and the number of seeds per pod. Cultivated cultivars of broad bean differed significantly in the length of the pods, however did not differ in the amount of pods and number of seeds (Table 3). In the cultivation without covering significantly the lowest number of pods per plant was characteristic for the broad bean cv 'Bizon'. That pods were also the longest among the cultivated cultivars, but contained the least seeds. In the studies by Jadczak et al. (2005) regarding evaluation of yields of selected cultivars of broad beans, the longest pods with the largest number of seeds, which were also characterized by the greatest length, thickness and width, were marked by the broad bean cv 'Bachus'. After perforated foil applied, the highest amount of pods with the largest length and number of seeds was significantly found in cv 'Bachus'. In the cultivation under polypropylene fibre, most of pods per plant produced the broad bean cv 'Bizon'. That pods had also the largest length. The most of seeds in pods of plant cultivated under polypropylene fibre was found in the broad bean cv 'Windsor Biały'.

After the biometric measurements, it was found that the seeds of the cultivated cultivars were characterized by different lengths (Table 4). The longest ones were the seeds of the broad bean cv 'Bizon'. The width and thickness of seeds was similar. Covering caused a significant increase in the width of the seeds, but the length and thickness did not differ significantly. A significant difference in the width of seeds was found at perforated foil cover. At perforated foil cover, the widest seeds were in the cv 'Windsor Biały'. In the cultivation without covering and after polypropylene fibre application, the width of seeds of cultivated cultivars was similar.

Conclusion

1. The highest yield of pods and seeds, irrespective of cultivars was obtained from the cultivation under polypropylene fibre. In the cultivation under polypropylene fibre, broad bean was also characterised by the largest number of pods per plant and biological productivity of yield.
2. Cultivated cultivars, irrespective of the kind of cover, produced similar amount of pods with similar number of seeds.
3. Biometric parameters of seeds of cultivated broad bean cultivars were similar. Higher values were achieved only by the seeds of cv 'Bizon'.

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