

## Effects of the growing season extension on Polish primocane-fruiting raspberry cultivars

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### Abstract

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Three primocane-fruiting raspberry cvs, Polana, Polka and Polesie, were evaluated for their performance under various early spring coverings during the 2010–2013 growing seasons. Three cultivation techniques were compared: covering plants with perforated plastic cover, covering plants with fibre cover (in early spring, for a period of about 1 month), mowing of young canes in the middle of May; the control combination were plants without covers and not mown. During each growing season, plant growth vigour, yielding and fruit quality (soluble solids and vitamin C content) were assessed. The use of low covers (perforated plastic cover and fibre cover) advanced the fruit ripening of the tested cultivars by about 2 weeks. The covers of raspberry plants also increased significantly yield of the early fruit (harvested in July and August) compared with the control. The investigated techniques can be recommended for implementation and use on commercial raspberry plantations to force early fruiting and thus increase their production potential in the summer-autumn period.

**Keywords:** *Rubus idaeus* L.; perforated plastic cover; fibre cover; shoot mowing; yield; fruit quality

According to the International Raspberry Organisation, the global raspberry harvest in 2013 totalled about 326,500 tons. This is about 19% less relative to 2012, when the total amount of the fruit collected worldwide was 402,800 t (FAOSTAT 2014). For many years, Poland has been the leading producer of raspberries in the world. According to the Central Statistical Office of Poland (GUS), 120,000 t of the fruit were collected in this country in 2013. This is considerably more than in Serbia (55,000 t), which is the second largest world producer of raspberries. About 50,000 t of the fruit comes from Chile, 13,000 t from the United Kingdom, 11,000 t from

France, and 10,000 t from China. Poland's position has been strengthened by the introduction into cultivation of new Polish varieties resulting from the breeding programme conducted for over thirty years by the Research Institute of Horticulture in Skierniewice. The aim of this programme was focused on introduction of varieties bearing fruit for an extended time period (summer/autumn) called 'primocane' cultivars to the commercial production (LEWANDOWSKI, ŻURAWICZ 2010, 2012).

One approach to accelerating growth, flowering and fruiting to permit a greater harvest before fall frost is to use row covers to warm the soil and

plants in spring. PRITTS *et al.* (1992) demonstrated that covering a field of primocane-fruiting raspberries with row cover before cane emergence, and then removing it when the canes are about 0.5 m tall, will allow fruit to ripen as much as 2 weeks earlier than uncovered plants. Primocane-fruiting raspberries can be also grown in a high tunnel to accelerate flowering and fruiting (DEMCHAK *et al.* 2003). High tunnels are now widely used in California to protect raspberries from weather vagaries and provide some season extension for both the spring and fall crops.

Another approach is to protect plants from frost while they are fruiting to extend the season later in fall (OLIVIERA *et al.* 1996; PITSIODIS *et al.* 2001). For example, a typical unprotected crop of cv. Heritage raspberries may be harvested for 5 weeks in the northeast until the first hard frost, but if grown under a tunnel that is covered with plastic in late summer, it may be harvested for 10 weeks or longer (PRITTS 2006).

The aim of the study was to evaluate the possibility of extending the fruit-bearing period of primocane raspberry varieties grown in the open field (fruiting during the summer-autumn period) by advancing the summer ripening as a result of covering raspberry plants with low covers (low tunnels) in early spring.

## MATERIAL AND METHODS

The study was conducted in 2010–2013 based on a two-factor field experiment. The experimental factors were: A – cultivation technique (cultivation under two types of cover: (1) perforated plastic cover (700 holes/m<sup>2</sup>), and (2) fibre cover (17 g); (3) mowing (in mid-May) young canes, with a height of about 40 cm growing from the crown, to delay fruiting; (4) control – the traditional cultivation of raspberries, B – cultivar (3 raspberry cultivars). Three Polish primocane-fruiting varieties: Polana, Polka and Polesie were used in the study. These varieties had been bred in the Experimental Orchard in Brzezna by Dr. Jan Danek and included in the Polish National List of Fruit Plant Varieties and in the Register of Varieties Protected by Plant Breeders' Rights in the years 1991, 2003, and 2006 (DANEK 2004; KRÓL *et al.* 2008). The planting material was produced traditionally in open-field stool beds. The experiment was established on May 6, 2010 in an experimental field with a Class IV podzolic soil at the Research

Institute of Horticulture Pomological Orchard in Skierniewice, Poland. After planting, the shoots were cut back just above the soil surface. The experiment was set up in a split-plot design, with four replications each with 5 plants planted at a spacing of 0.5 × 3.75 m, the size of the plot was 11.25 m<sup>2</sup>. A total of 240 plants were planted in the experiment (3 cultivars × 4 cultivation methods × 4 replicates × 5 plants). Both types of low covers were used in the early spring: in 2011 – from March 15 to April 14, in 2012 – from March 21 to April 20, and in 2013 – from April 16 to May 15. During the growing season, the plants were fertilised, mechanical cultivation between rows was performed several times, and weeds in the rows were regularly controlled. Automatically controlled drip irrigation system was used to water the plots. Each year, the following measurements and observations were collected:

- plant growth vigour – on a 1–5 rating scale: 1 – very low growth vigour, 5 – very strong growth vigour;
- plant yielding (kg/plant, 7 canes were derived from each crown);
- mean fruit weight (g);
- fruit ripening time;
- soluble solids content of fruit – using Rudolph J-157 refractometer (Rudolph Research Analytical, Hackettstown, USA);
- vitamin C content of fruit (using an RQ-Easy reflectometer and Merck test strips (Merck KGaA, Darmstadt, Germany)).

The data were analysed with an analysis of variance; to assess the differences between means, Duncan's *t*-test was used at a 5% significance level.

## RESULTS AND DISCUSSION

The results of the assessment of plant growth vigour, yielding and fruit quality are presented in Tables 1–3. In 2011–2013, the most vigorously growing plants were those of the cv. Polesie; a little less vigorous were the plants of cv. Polka, and the least vigorous those of cv. Polana. Information on a similar behaviour of plants of these cultivars can be found in the literature (KRÓL *et al.* 2008). Both perforated plastic cover and fibre cover accelerated fruit ripening of the tested cultivars by about 2 weeks (Table 1). The covers significantly enhanced yield of the early fruit (harvested in July and August) compared with the control (Fig. 1).

Table 1. Plant growth vigour and fruit ripening time of three raspberry cultivars as affected by different methods of cultivation (Skierniewice, 2011–2013)

Cultivar – treatment	Plant growth vigour (1–5)*				First fruit harvest		
	2011	2012	2013	average	2011	2012	2013
<b>Polesie</b> – control	3.5 <sup>de**</sup>	3.4 <sup>d</sup>	3.3 <sup>de</sup>	3.4 <sup>cd</sup>	July 5	July 9	July 12
– plastic cover	4.4 <sup>h</sup>	4.5 <sup>f</sup>	4.5 <sup>i</sup>	4.5 <sup>h</sup>	June 26	June 29	July 1
– fibre cover	4.1 <sup>g</sup>	4.2 <sup>e</sup>	4.2 <sup>h</sup>	4.2 <sup>g</sup>	June 30	July 2	July 3
– shoot mowing	3.4 <sup>cd</sup>	3.3 <sup>c</sup>	3.1 <sup>b–d</sup>	3.3 <sup>c</sup>	July 20	July 23	July 31
– average	3.9 <sup>c</sup>	3.9 <sup>c</sup>	3.8 <sup>c</sup>	3.8 <sup>c</sup>	June 26	June 29	July 1
<b>Polka</b> – control	3.2 <sup>bc</sup>	3.0 <sup>b</sup>	3.1 <sup>b–d</sup>	3.1 <sup>b</sup>	July 5	July 9	July 12
– plastic cover	3.9 <sup>fg</sup>	3.7 <sup>d</sup>	3.8 <sup>g</sup>	3.8 <sup>f</sup>	June 27	June 29	July 1
– fibre cover	3.7 <sup>ef</sup>	3.5 <sup>cd</sup>	3.6 <sup>fg</sup>	3.6 <sup>e</sup>	June 27	June 29	July 1
– shoot mowing	3.1 <sup>b</sup>	2.9 <sup>ab</sup>	3.0 <sup>a–c</sup>	3.0 <sup>b</sup>	July 20	July 23	July 31
– average	3.5 <sup>b</sup>	3.3 <sup>b</sup>	3.4 <sup>b</sup>	3.4 <sup>b</sup>	June 27	June 29	July 1
<b>Polana</b> – control	2.7 <sup>a</sup>	2.8 <sup>ab</sup>	2.9 <sup>ab</sup>	2.8 <sup>a</sup>	July 5	July 9	July 12
– plastic cover	3.5 <sup>de</sup>	3.5 <sup>cd</sup>	3.4 <sup>ef</sup>	3.5 <sup>de</sup>	June 27	June 29	July 1
– fibre cover	3.3 <sup>b–d</sup>	3.3 <sup>c</sup>	3.2 <sup>c–e</sup>	3.3 <sup>c</sup>	June 30	July 2	July 3
– shoot mowing	2.6 <sup>a</sup>	2.7 <sup>a</sup>	2.8 <sup>a</sup>	2.7 <sup>a</sup>	July 18	July 20	July 29
– average	3.0 <sup>a</sup>	3.1 <sup>a</sup>	3.1 <sup>a</sup>	3.1 <sup>a</sup>	June 27	June 29	July 1
Average for cultivation techniques	control			3.1 <sup>b</sup>	July 5	July 9	July 12
	plastic cover			3.9 <sup>d</sup>	June 26	June 29	July 1
	fiber cover			3.7 <sup>c</sup>	June 27	June 29	July 1
	shoot mowing			3.0 <sup>a</sup>	July 18	July 20	July 29

\*rating scale (1–5): 1 – very low growth vigour, 5 – very strong growth vigour; \*\* means in columns followed by the same letter do not differ significantly at  $P = 0.05$  according to Duncan's multiple range test

The size of the fruit yield from the different cultivars depended to a large extent on the weather, low winter temperatures, drought in the spring and early summer, as well as on the age of the plantation (WIENIARSKA 1992). The results obtained in the experiment were influenced by the weather conditions in 2011 and 2012. Ground frosts occurred:  $-1.5^{\circ}\text{C}$  on May 4 and 5, 2011 and  $-0.5^{\circ}\text{C}$  on May 8 and 9, 2012. At that time, the raspberry canes were about 30–40 cm tall. During those days, the low temperatures damaged the tips of the canes, especially in the cv. Polana. As a result, there was a temporary inhibition in the growth of canes, followed by very strong branching. This type of growth had a negative effect on fruit yield and fruit ripening time. The highest marketable yield was obtained from the cv. Polka – 23.1 kg/plot

(20.5 t/ha) in 2011, 22.5 kg/plot (20.0 t/ha) in 2012, and 16.2 kg/plot (14.4 t/ha) in 2013 under fibre cover, and 22.5 kg/plot (20.0 t/ha) in 2011, 21.9 kg/plot (19.5 t/ha) in 2012, and 15.1 kg/plot (13.4 t/ha) in 2013 under perforated plastic cover. Slightly lower yields from the same combinations were obtained for the cv. Polesie, with the cv. Polana being the lowest-yielding variety. For the cv. Polesie under fibre cover, the yield per plot was from 38% in 2011 and 2012 to 44% in 2013 higher than in the control. The increase in yield of cv. Polana ranged from 25% to 41% depending on the season, and in the cv. Polka from 23% to 30%.

The largest berries were produced by the cv. Polesie (4.6–5.2 g), slightly smaller by cv. Polka (3.9–4.3 g), and the smallest by cv. Polana (2.8–3.2 g) (Table 2). The optimum flavour, firmness, size and colour of

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Table 2. Yielding of three raspberry cultivars as affected by different methods of cultivation (Skierniewice, 2011–2013)

Cultivar – treatment	Yield (kg/plot)				Mean fruit weight (g)			
	2011	2012	2013	average	2011	2012	2013	average
<b>Polesie</b> – control	15.2 <sup>f</sup>	14.7 <sup>f</sup>	10.1 <sup>c</sup>	13.3 <sup>cd</sup>	4.9 <sup>cd</sup>	4.7 <sup>d</sup>	4.6 <sup>c</sup>	4.7 <sup>e</sup>
– plastic cover	19.9 <sup>i</sup>	19.2 <sup>i</sup>	13.4 <sup>f</sup>	17.5 <sup>ef</sup>	5.2 <sup>e</sup>	5.1 <sup>f</sup>	5.0 <sup>d</sup>	5.1 <sup>g</sup>
– fibre cover	21.0 <sup>j</sup>	20.3 <sup>j</sup>	14.6 <sup>g</sup>	18.6 <sup>fg</sup>	5.1 <sup>de</sup>	5.0 <sup>ef</sup>	4.8 <sup>cd</sup>	5.0 <sup>f</sup>
– shoot mowing	13.6 <sup>c</sup>	13.1 <sup>c</sup>	8.2 <sup>b</sup>	11.6 <sup>bc</sup>	4.8 <sup>c</sup>	4.8 <sup>de</sup>	4.7 <sup>c</sup>	4.8 <sup>e</sup>
– average	17.4 <sup>b</sup>	16.8 <sup>b</sup>	11.6 <sup>b</sup>	15.3 <sup>b</sup>	5.0 <sup>c</sup>	4.9 <sup>c</sup>	4.8 <sup>c</sup>	4.9 <sup>c</sup>
<b>Polka</b> – control	18.4 <sup>h</sup>	18.2 <sup>h</sup>	12.5 <sup>e</sup>	16.4 <sup>e</sup>	4.1 <sup>b</sup>	4.0 <sup>c</sup>	3.9 <sup>b</sup>	4.0 <sup>c</sup>
– plastic cover	22.5 <sup>k</sup>	21.9 <sup>k</sup>	15.1 <sup>h</sup>	19.8 <sup>gh</sup>	4.3 <sup>b</sup>	4.2 <sup>c</sup>	4.1 <sup>b</sup>	4.2 <sup>d</sup>
– fibre cover	23.1 <sup>l</sup>	22.5 <sup>l</sup>	16.2 <sup>i</sup>	20.6 <sup>h</sup>	4.2 <sup>b</sup>	4.2 <sup>c</sup>	4.2 <sup>b</sup>	4.2 <sup>d</sup>
– shoot mowing	15.7 <sup>g</sup>	15.2 <sup>g</sup>	10.1 <sup>c</sup>	13.7 <sup>d</sup>	4.1 <sup>b</sup>	4.1 <sup>c</sup>	4.0 <sup>b</sup>	4.1 <sup>c</sup>
– average	19.9 <sup>c</sup>	19.5 <sup>c</sup>	13.5 <sup>c</sup>	17.6 <sup>c</sup>	4.2 <sup>b</sup>	4.1 <sup>b</sup>	4.1 <sup>b</sup>	4.1 <sup>b</sup>
<b>Polana</b> – control	11.8 <sup>b</sup>	11.4 <sup>b</sup>	9.0 <sup>b</sup>	10.7 <sup>b</sup>	2.9 <sup>a</sup>	2.8 <sup>a</sup>	2.9 <sup>a</sup>	2.9 <sup>a</sup>
– plastic cover	14.3 <sup>d</sup>	13.6 <sup>d</sup>	11.4 <sup>d</sup>	13.1 <sup>cd</sup>	3.1 <sup>a</sup>	3.2 <sup>b</sup>	3.1 <sup>a</sup>	3.1 <sup>b</sup>
– fiber cover	14.7 <sup>e</sup>	14.2 <sup>e</sup>	12.7 <sup>e</sup>	13.9 <sup>d</sup>	3.0 <sup>a</sup>	3.0 <sup>ab</sup>	3.1 <sup>a</sup>	3.0 <sup>b</sup>
– shoot mowing	9.3 <sup>a</sup>	9.0 <sup>a</sup>	7.1 <sup>a</sup>	8.5 <sup>a</sup>	3.0 <sup>a</sup>	3.1 <sup>b</sup>	3.0 <sup>a</sup>	3.0 <sup>b</sup>
– average	12.5 <sup>a</sup>	12.1 <sup>a</sup>	10.1 <sup>a</sup>	11.5 <sup>a</sup>	3.0 <sup>a</sup>	3.0 <sup>a</sup>	3.0 <sup>a</sup>	3.0 <sup>a</sup>
Average for cultivation techniques	control			13.5 <sup>b</sup>	3.86 <sup>a</sup>			
	plastic cover			16.8 <sup>c</sup>	4.14 <sup>d</sup>			
	fibre cover			17.7 <sup>c</sup>	4.06 <sup>c</sup>			
	shoot mowing			11.3 <sup>a</sup>	3.96 <sup>b</sup>			

means in columns followed by the same letter do not differ significantly at  $P = 0.05$  according to Duncan's multiple range test

the berries can be obtained by picking those that are at the right stage of maturity, which is achieved primarily by harvesting repeatedly (ROLBIECKI et al.

2002; KRAWIEC, RYBCZYŃSKI 2010), as was done in this experiment. Berries of the cv. Polka contained the highest amounts of soluble solids (extract) –

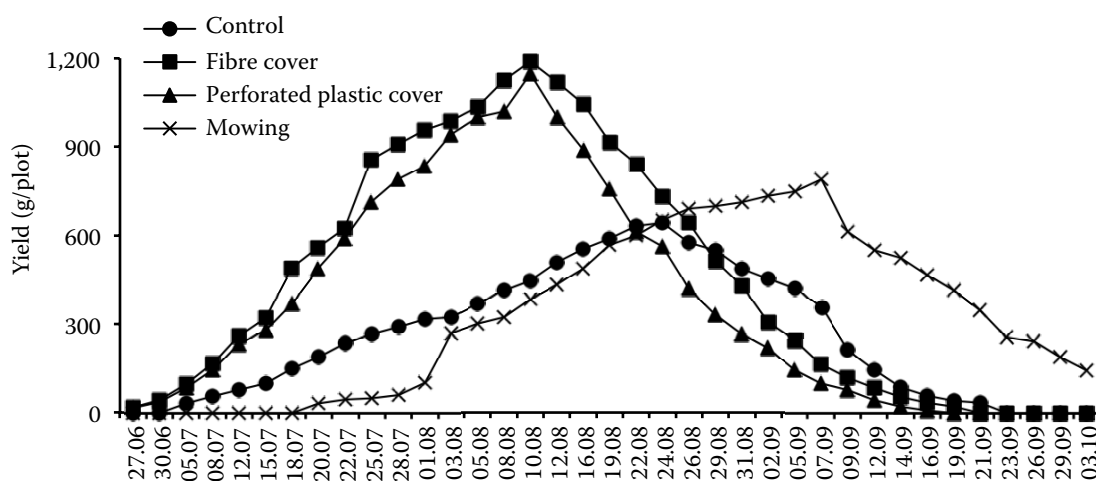


Fig. 1. Yield dynamics of raspberry cv. Polka in 2011 (first year of yielding, Skierniewice)

Table 3. Fruit quality of three raspberry cultivars as affected by different methods of cultivation (Skierniewice, 2011–2013)

Cultivar – treatment	Soluble solids content (Brix)				Ascorbic acid content (mg/100 ml)			
	2011	2012	2013	average	2011	2012	2013	average
<b>Polesie</b> – control	11.28 <sup>f</sup>	11.12 <sup>d</sup>	10.89 <sup>h</sup>	11.10 <sup>b</sup>	81 <sup>h</sup>	82 <sup>d</sup>	80 <sup>d</sup>	81 <sup>d</sup>
– plastic cover	11.47 <sup>h</sup>	11.35 <sup>h</sup>	11.31 <sup>f</sup>	11.38 <sup>cd</sup>	87 <sup>i</sup>	88 <sup>e</sup>	85 <sup>e</sup>	86.7 <sup>f</sup>
– fibre cover	11.19 <sup>e</sup>	11.17 <sup>e</sup>	11.24 <sup>e</sup>	11.20 <sup>bc</sup>	85 <sup>i</sup>	84 <sup>d</sup>	82 <sup>d</sup>	83.7 <sup>e</sup>
– shoot mowing	10.95 <sup>c</sup>	11.23 <sup>f</sup>	11.09 <sup>c</sup>	11.09 <sup>b</sup>	79 <sup>gh</sup>	81 <sup>d</sup>	80 <sup>d</sup>	80.0 <sup>d</sup>
– average	11.22 <sup>b</sup>	11.22 <sup>b</sup>	11.13 <sup>b</sup>	11.19 <sup>b</sup>	83.0 <sup>c</sup>	83.8 <sup>b</sup>	81.8 <sup>b</sup>	82.8 <sup>c</sup>
<b>Polka</b> – control	11.33 <sup>g</sup>	11.24 <sup>f</sup>	11.15 <sup>d</sup>	11.24 <sup>bc</sup>	72 <sup>bc</sup>	71 <sup>a</sup>	70 <sup>a</sup>	71.0 <sup>a</sup>
– plastic cover	11.52 <sup>i</sup>	11.43 <sup>i</sup>	11.47 <sup>g</sup>	11.47 <sup>d</sup>	78 <sup>fg</sup>	77 <sup>c</sup>	75 <sup>c</sup>	76.7 <sup>c</sup>
– fiber cover	11.27 <sup>f</sup>	11.33 <sup>h</sup>	11.35 <sup>f</sup>	11.32 <sup>cd</sup>	75 <sup>de</sup>	74 <sup>a-c</sup>	73 <sup>bc</sup>	74.0 <sup>b</sup>
– shoot mowing	11.13 <sup>d</sup>	11.28 <sup>g</sup>	11.24 <sup>e</sup>	11.22 <sup>bc</sup>	70 <sup>ab</sup>	73 <sup>ab</sup>	71 <sup>ab</sup>	71.3 <sup>a</sup>
– average	11.31 <sup>c</sup>	11.32 <sup>c</sup>	11.30 <sup>c</sup>	11.31 <sup>c</sup>	73.8 <sup>b</sup>	73.8 <sup>a</sup>	72.3 <sup>a</sup>	73.3 <sup>b</sup>
<b>Polana</b> – control	10.98 <sup>c</sup>	10.91 <sup>a</sup>	10.82 <sup>a</sup>	10.90 <sup>a</sup>	71 <sup>a-c</sup>	72 <sup>ab</sup>	70 <sup>a</sup>	71.0 <sup>a</sup>
– plastic cover	11.19 <sup>e</sup>	11.11 <sup>d</sup>	11.08 <sup>c</sup>	11.13 <sup>b</sup>	76 <sup>ef</sup>	74 <sup>a-c</sup>	73 <sup>bc</sup>	74.3 <sup>b</sup>
– fiber cover	10.87 <sup>b</sup>	10.96 <sup>b</sup>	10.94 <sup>b</sup>	10.92 <sup>a</sup>	73 <sup>cd</sup>	75 <sup>bc</sup>	72 <sup>ab</sup>	73.3 <sup>b</sup>
– shoot mowing	10.75 <sup>a</sup>	11.03 <sup>c</sup>	10.90 <sup>b</sup>	10.89 <sup>a</sup>	69 <sup>a</sup>	72 <sup>ab</sup>	70 <sup>a</sup>	70.3 <sup>a</sup>
– average	10.95 <sup>a</sup>	11.00 <sup>a</sup>	10.94 <sup>a</sup>	10.96 <sup>a</sup>	72 <sup>a</sup>	73.3 <sup>a</sup>	71.3 <sup>a</sup>	72.3 <sup>a</sup>
Average for cultivation techniques	control			11.08 <sup>a</sup>				
	plastic cover			11.33 <sup>b</sup>				
	fiber cover			11.15 <sup>a</sup>				
	shoot mowing			11.07 <sup>a</sup>				

means in columns followed by the same letter do not differ significantly at  $P = 0.05$  according to Duncan's multiple range test

from 11.13% to 11.47%. Those of cv. Polesie were the richest in vitamin C (79–88 mg of vitamin C in 100 ml of juice) (Table 3). This is indeed twice the amount of vitamin C reported in the literature for raspberries. However, many publications indicated high variability in the chemical composition of the raspberry fruit as dependent on cultivation- and cultivar-related factors (OLIVIERA et al. 1996; KRÓL et al. 2008; LEWANDOWSKI, ŻURAWICZ 2010, 2012). For most of the components, there can be even a twofold difference between different years (KUNACHOWICZ et al. 2005).

## CONCLUSION

Based on the results from the experiment, it can be concluded that the use of low covers (perforated plastic cover and fiber cover) in the early spring advances vegetative growth of canes and is beneficial

for early yielding of raspberry plants of all three tested cultivars. This cultivation method can be proposed for implementation and the use of primocane-fruited raspberry on commercial plantations in order to achieve early fruiting and thus increase their production potential in the summer-autumn period.

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