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Influence of Temperature Sums on Growth and Fruit Mass and Yield of Strawberry

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Summary

Strawberry growth in Northern Europe is limited by a combination of drought, low temperatures, spring and winter frosts, the latter particularly without snow cover, resulting in a short vegetation period. Hence, the influence of temperature sums, cultivars, and blossom weevil *Anthonomus rubi* on fruit mass and yield were examined during 1999–2003 in Estonia. Strawberry cv. 'Korona' required the lowest temperature sum (>10 °C) for flowering and cv. 'Kent' for ripening out of the four cultivars tested, i.e. 'Senga Sengana', 'Kent', 'Korona' and 'Polka', while cv. 'Polka' withstood extreme conditions like drought, high temperature and spring frosts with the retention of a good fruit yield. Temperature sums were found a suitable approach to describe the ecophysiological adaptation of strawberry plants to the harsh climate in Northern Europe.

Zusammenfassung

Einfluß von Temperatursummen auf Wachstum, Ertrag und Fruchtgewicht von Erdbeeren. Wachstum und Ertrag von Erdbeeren in Nordeuropa werden durch geringe Temperaturen wie Spät- und Winterfröste – vor allem in Zeiten ohne Schneeauflage – und durch kurze Vegetationszeiten begrenzt. Daher sollte der Einfluss von Temperatursummen über 10 °C auf Wachstum und Fruchtertrag in Abhängigkeit von Sorte und Blütenbildung und dem Erdbeerblütenstecher *Anthonomus rubi* in einem fünfjährigen Feldversuch in Estland untersucht werden. Von den vier untersuchten Sorten – einschließlich 'Senga Sengana' als Kontrolle – benötigte 'Korona' zum Blühen und 'Kent' zur Fruchtreife die geringste Temperatursumme. Von den vier Erdbeersorten war 'Polka' am wenigsten anfällig gegenüber Trockenheit und Temperaturextremen wie Frösten. Temperatursummen erwiesen sich als geeignetes Mittel zur Ermittlung der ökophysiologischen Anpassungsmöglichkeiten einer Erdbeersorte an die harten Anbaubedingungen Nordeuropas.

Key words. strawberry – ecology – inflorescence – fruit – yield – frost – *Anthonomus rubi* – temperature sum – winter hardiness

Introduction

In Northern Europe, weather conditions are one of the factors limiting strawberry cultivation and winter hardiness (NES 1997; HIETERANTA and MATALA 2002), as flowers of differ in their frost hardiness. In the present article on five-year-trials, we try to examine the weather influence, mainly temperature, and precipitation, cultivar and abundance of *Anthonomus rubi* on strawberry yield and fruit mass using Estonia as an example for Northern Europe.

Material and Methods

The trials were carried out at the Polli Horticultural Institute in 1999–2003 with four replicas with 20 plants, black plastic mulch and a planting density of 1.40 x 0.25 m with cultivars 'Polka', 'Korona' and 'Kent' and 'Senga Sengana' as control. The soil was a soddy podzolic clay loam, fertilised with 80 t ha^{-1} manure and PK-mineral fertilizers (both 100 kg in active ingredient) before planting and Ferticare 6-11-31 and $Ca(NO_3)_2$ later. The data were analysed statistically using two-factor ANOVA.

Weather condition and temperature sums

The weather during the trials was various. In the beginning of December 1998 the temperature dropped to –16 °C without snow cover. There were spring frosts in May 1999 (–5.5 °C on 12 May). June and July 1999 were relatively warm. The winter of 1999/2000 was favourable for strawberry over-wintering. There were some spring frosts with the minimum temperature –5 ° C and scarce precipitation. June 2000 had moderate temperatures and July was hot and rainy.

The winter of 2000/2001 was favourable for strawberry wintering as well. On 13 May the temperature dropped to –1.5 °C and on 1 June to –0.5 °C. It was moderate temperature in June, July was hot, enough precipitation, but in the second decade of July it was too rainy.

The winter 2001/2002 was favourable for strawberry. The spring was very droughty, the minimum temperature in May was 0 °C, whereas the daytime maxi-

mum temperature was +23 °C. The drought continued in June and in July 2002 the temperatures were relatively high.

The most severe winter during the trial period was in 2002/2003. On 16 December the temperature dropped to –19 °C, the snow cover was only 2 cm thick. On 11 January 2003 the temperature dropped to –32.5 °C. There were no night frosts in May. Temperature sums were defined here for the purpose of this ecophysiological manuscript as temperatures exceeding 10 °C.

Results

Temperature sums and temperature requirement for flowering and yield

'Korona' flowered first and 'Korona' needed a smaller sum of active temperatures (the mean of five years was 87 °C) than 'Senga Sengana' (Table 1). In all strawberry cultivars tested, the fruit ripened the earliest in 2002. The difference of yield ripening in cultivars was even less than that in blossoming. 'Kent' started flowering after 'Korona' and also needed a smaller sum of active temperatures (211 °C) than 'Senga Sengana' (263 °C) (Table 1).

Spring frosts and Anthonomus rubi

Spring frost in 2002 damaged the many flowers of cv. 'Kent'. The damage of the blossom weevil *Anthonomus rubi* was weak in 1999, 2001, and 2002. Only in 2003 blossom weevil damages were serious compared with the control cultivar 'Senga Sengana' the cultivar 'Korona' had 32 % more damage.

Yield and fruit mass

In most years the four cultivars had the yield at the same level with the control cultivar 'Senga Sengana', except in 2000 when yield of 'Korona' was higher than that of 'Senga Sengana' (Table 2) and in 2001 yield of all cultivars was lower than of 'Senga Sengana'. In 2002 'Polka' passed the level of the control cultivar yield, as 'Kent' had considerably lower yield than 'Senga Sengana'. Compared with 1999 'Polka' had a better yield in 2000 and 2002, the cultivar 'Korona' yield was better in 2000 and 2001 and the cultivar 'Senga Sengana' in 2001. The yield of the cultivar 'Korona' decreased in 2002 and 2003 and the same was with the cultivar 'Kent' in 2001–2003 and with 'Senga Sengana' in 2003 (Table 2). In the trials founded in 1998 the fruit mass of all the cultivars was bigger in first yield than in the following two years, but no significant difference in fruit size of all the cultivars was recorded (Table 2).

Discussion

The beginning of flowering and yielding

The beginning of flowering and its progress of the strawberry cultivars is mostly influenced by weather conditions, especially temperature (BATTERY et al. 1998; LEECH et al. 2002; TAYLOR 2002). In the trials the difference of flowering by years was greater than by the cultivars. 'Korona' was the first cultivar that started flowering. The fruits of the cultivar 'Kent' ripened earlier than the fruits of control cultivar. The cultivar 'Polka' had the same beginning of flowering and fruit ripening as the control cultivar in most years. The same results were obtained in Hungary (DENES 1997). Relatively early and simultaneous beginning of yield ripening was in 2002, when May with 8.4 mm precipitation and beginning of June with 3.6 mm precipitation in the first decade was droughty. Relatively high sum of active temperatures of 203.4 °C appeared in June, the maximum temperature was 29 °C. Ripening was late in 2003, when May and June were relatively cool with the sum of active temperatures of 87.3 °C and 123.9 °C respectively.

Table 1. Beginning of flowering and harvest of four strawberry cultivars and temperature sums >10 °C until the beginning of flowering and harvest at Polli in 1999–2003.

Cultivar/year	1999	2000	2001	2002	2003	Temperature sum >10 °C
Beginning of flowering						
'Senga Sengana' (control)	1.06	22.05	27.05	23.05	10.06	99.7
'Polka'	2.06	22.05	23.05	26.05	9.06	100.4
'Korona'	1.06	15.05	23.05	18.05	6.06	86.7
'Kent'	31.05	22.05	23.05	23.05	9.06	98.3
						LSD ($P < 0.05$) 10.9
Beginning of harvest						
'Senga Sengana' (control)	22.06	22.06	29.06	17.06	7.07	263.4
'Polka'	21.06	22.06	29.06	17.06	5.07	246.6
'Korona'	22.06	19.06	29.06	17.06	3.07	229.3
'Kent'	18.06	15.06	27.06	17.06	30.06	211.5
						LSD ($P < 0.05$) 13.5

Table 2. Fruit mass and yield of plant (g) at Polli in 1999–2003.

Cultivar/year	1999	2000	2001	2002	2003	Mean
Fruit mass (g)						
'Senga Senga' (control)	9.8	7.1	8.0	8.2	9.9	8.6
'Polka'	10.5	7.8	7.3	13.8	12.8	10.4
'Korona'	10.1	6.9	7.7	9.9	12.1	9.3
'Kent'	11.1	7.8	8.4	10.7	11.5	9.9
Mean	10.4	7.4	7.8	10.6	11.6	
LSD variant ($P < 0.005$) 1.8; LSD cultivar ($P < 0.005$) 0.8; LSD year ($P < 0.005$) 0.9						
Yield of plant (g)						
'Senga Senga' (control)	258	302	454	208	180	280.4
'Polka'	238	330	299	330	192	277.8
'Korona'	236	380	394	199	147	271.2
'Kent'	284	276	223	101	194	215.6
Mean	254	322	342.5	209.5	178.2	
LSD variant ($P < 0.005$) 56.1; LSD cultivar ($P < 0.005$) 25.1; LSD year ($P < 0.005$) 28.0						

Damages of spring frosts and Anthonomus rubi

Spring frosts in four out of five years of trials did cut the number of flowers. The flowers were very much damaged in the spring of 2002, when the weather during pre-flowering period was warm, in the second decade of May and in the beginning of the third decade the temperature dropped to 0 °C. The temperature on the ground was even lower which caused strong damages. A very great day and night temperature fluctuation (24 °C) might have caused even more severe damage. The flowers of the cultivar 'Kent' are supposed to be more sensitive to spring frosts than other cultivar flowers. 30 % of flowers were damaged in the cultivar 'Kent'. The advantage of the cultivar 'Kent' as an early cultivar is its relatively late beginning of flowering (Table 1). The flowers of 'Senga Sengana' have been relatively resistant to spring frosts. In collection of strawberry the cultivar 'Induka', its one parent being 'Senga Sengana', has especially resistant flowers. One parent of 'Polka' and 'Korona' has been in its turn 'Induka'. Thus it can be supposed that the resistance of flowers to spring frosts is inherited from cultivar 'Senga Sengana'. As the trials proved, spring frosts did damage strawberry flowers more or less in most years, but more severe damage was in one year out of five.

The strawberry blossom weevil *Anthonomus rubi* can cause a serious damage to strawberry flowers. Last years in general it has been very minimal. The damage stage depends on a cultivar (SIMPSON et al. 1997; KIKAS and LIBEK 2002). At the same time the exchange of stronger to weaker damage periods have been noticed. In 2003 the blossom weevil damage was strong. The damage expanded as the previous summer and autumn had been droughty and hot and the number of flowers of the strawberry cultivars in 2003 was lower compared to previous years.

Yield and fruit mass

Strawberry cv. 'Polka' tolerated extreme environmental conditions in 2002 with a retention of good yield (Table 2) as in cv. 'Senga Sengana'. The very small yield from the cultivar 'Kent' in 2002 was due to very extensive (30 %) spring frost damages. The small yield in 2003 was the result of low number of flowers, which in its turn, was reduced by the blossom weevil damage. In the trial established in 1998 the fruit masses of all the cultivars in the first crop year were bigger than in the two following years. The cultivars 'Kent' and 'Polka' had bigger fruits than others as average of years (Table 2). By the regression analysis the strong negative correlation between fruit mass and yield was noticed. Rather weak negative correlation was between the number of flowers and fruit mass. The negative correlation of fruit weight with flower number has been mentioned in other research (HORTYNSKI 1979; HANDLEY and DILL 2003) suggesting that the number of fruit a cultivar can produce has more influence on yield than the size of fruit it produces.

Conclusion

In the harsh climate of Northern Europe, relatively early and simultaneous beginning of ripening was observed in years, when June was droughty with relatively high temperatures. By contrasts, ripening was late in years, when May and June were relatively cool.

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