Viability of plum ovules at different temperatures

By R CEROVIĆ, Đ RUŽIĆ and N MIĆIĆ

ARI 'SERBIA', Fruit and Grape Research Centre, 32000 Čačak, FR Yugoslavia,
"Faculty of Agriculture, 78000 Banja Luka, Bosnia and Herzegovina

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Summary

The viability of ovules was studied in five plum cultivars under laboratory conditions at four constant temperatures: 5°C, 10°C, 15°C and 20°C and under field conditions over two years. During 10 days from the onset of full bloom, ovule viability in cvs 'Čačanska Rana', 'Čačanska Najbolja' and 'Čačanska Lepotica' was between 80-100 % at the temperatures of 5°C, 10°C and 15°C, in both years. In the same period, ovule viability in cvs 'Wangenheim Frühzwetsche' and 'Požegača' was lower, but never below 50%. At the constant temperature of 20°C, all plum cultivars showed a decline in longevity of ovule viability, which was pronounced in cv. 'Čačanska Rana'. During the 10 days from the onset of full bloom, ovule viability in all five plum cultivars under field conditions showed a high viability, which approximated to the ovule viability of the cultivars at the constant temperatures of 5°C, 10°C and 15°C, in both years. Determination of the longevity of ovule viability in the mentioned plum cultivars is of great importance due to its effect on the effective pollination period and fertilisation success. This paper deals in detail with the interrelations between the temperature effects on ovule viability, pollen tube growth and fertilisation, as well as on fruit setting.

Key words: Plum cultivars, ovule fluorescence, ovule viability, temperature

Introduction

The viability of ovules in fruit crops is a factor directly affecting the effective pollination period (E.P.P.) (Williams, 1970). In stone fruits, short ovule viability is especially pronounced in cherries (Stösser & Anvari, 1982; Postweiler, Stösser & Anvari, 1985). Higher temperatures accelerate the ageing of ovules in sour cherry, thus diminishing the efficacy of fertilisation (Cerović & Ružić, 1992b). In plum, the ageing of ovules is somewhat slower than in cherries, where at the constant temperature of 20°C, all ovules lose viability in three to four days (Stösser & Anvari, 1990). On the other hand, low temperatures can inhibit pollen tube growth in the pistil, so that the pollen cannot reach the ovary before the onset of the ageing of the ovules (Keulemans & Van Laer, 1987). Both factors, viability of ovules and the velocity of pollen tube growth in vivo, in some pollination combinations in certain fruit crops, directly affect the degree of fertilisation (Cerović & Mićić, 1996).

This paper aimed to study the ovule viability at different temperatures under laboratory and field conditions during full bloom in the plum cultivars ‘Čačanska Rana’, ‘Čačanska Najbolja’ and ‘Čačanska Lepotica’ and their parental pairs ‘Wangenheim Frühzwetsche’ and ‘Požegača’. In the work done so far, ‘Čačanska Rana’ and ‘Čačanska Najbolja’ have been shown to be prone to irregular bearing and have been defined as partially self-compatible cultivars (Ogašanović, 1985). Determination of the longevity of ovule viability in the mentioned plum cultivars is of great importance due to its effect on E.P.P. (Williams, 1970) and fertilisation success (Cerović & Mićić, 1999).

Materials and Methods

The plum cultivars ‘Čačanska Rana’, ‘Čačanska Najbolja’, ‘Čačanska Lepotica’, ‘Wangenheim Frühzwetsche’ and ‘Požegača’ were used for the experiments. For the experiment under laboratory conditions, branches of the cultivars studied, 40-50 cm in length, were detached from the trees when most of the flowers were in the late balloon stage. The stem ends were cut off under water in the laboratory and placed in a 5% sucrose solution overnight. Open flowers were removed and the remaining ones were emasculated. Several twigs with non-emasculated flowers were left as the control of the onset of full bloom under laboratory conditions. The next day most of blossoms from the control were open, so this day was considered as the onset of full bloom in those cultivars. Twigs of those cultivars were placed in water in controlled-temperature chambers at constant
temperatures of 5°C, 10°C, 15°C and 20°C. In the field, emasculated flowers on the previously chosen branches in the late balloon stage were bagged to avoid accidental pollination.

Thirty pistils per cultivar were collected every day under laboratory and field conditions from the onset of full bloom, with day ten of full bloom inclusive. Samples were fixed in FPA (40% formaldehyde: propionic acid : 70% ethyl alcohol, 5 : 5 : 90). The viability of ovules was assessed using the fluorescent-microscopic method described by Anvari & Stösser (1978a,b). Entire ovules showing very intensive fluorescence indicated that they could not be fertilised and should be therefore considered as non-viable (Stösser & Anvari, 1982). Daily temperatures were recorded during full bloom of plum cultivars in field trials. Experiments were conducted over 2 years, during 1986 and 1987.

Results

As with other stone fruits, the plum ovary contains two ovules. One of the ovules, the primary one, develops into the seed if fertilised, whereas the other, the secondary one, atrophies at the very onset of full bloom, showing intense fluorescence. This trait of the secondary ovule is common to all the plum cultivars studied and was observed in all experimental conditions. Unlike the secondary ovule, the primary ovule continues developing, spreading through the ovary locule (Fig. 1a). The occurrence of fluorescence in some ovules can be first observed in the calaza region immediately after the onset of full bloom, no matter whether it is temperature induced or is a cultivar-specific trait (Fig. 1b). In the later period of full bloom, fluorescence spreads to the micropyle of the ovule, finally spreading through the entire ovule (Fig. 1c).

Ovule viability in the mentioned plum cultivars was studied only in those primary ovules, which completely show very intensive fluorescence, an indicator of the loss of their viability (Fig. 1d). In cvs ‘Čačanska Rana’, ‘Čačanska Najbolja’ and ‘Čačanska Lepotica’ at the temperatures of 5°C, 10°C and 15°C ovule viability was between 80% - 100% during 10 days of full bloom, in both years (Fig. 2a,b,c). Over the same period, ‘Wangenheims Frühzwetsche’ and ‘Požegača’ showed a higher percentage of fluctuation

Fig. 1. (a) A viable ovule in the ovary locule without fluorescence; (b) occurrence of fluorescence in the calaza region of ovule; (c) fluorescence of ovule spreading to the micropyle of the ovule; (d) intensive fluorescence of the entire ovule, indicating a non-viable ovule.
of ovule viability, but never below 50% (Fig. 2d,e). A decline of ovule viability was observed at the temperature of 20°C, in all the plum cultivars studied, in both years. It was most pronounced in 'Ćačanska Rana'. At the end of day 10, only 10% of viable ovules could be observed (Fig. 2a). This indicates that the constant temperature of 20°C is a limiting factor for the ovule viability in all the evaluated plum cultivars.
along with previously mentioned cultivar specificity.

In this paper, parental pair 'Wangenheims Fruhzwetsche' and 'Požegača', especially 'Wangenheims Fruhzwetsche', showed a somewhat higher susceptibility of ovules than 'Čačanska Rana', 'Čačanska Najbolja' and 'Čačanska Lepotica', in relation to the evaluated constant temperatures.

On the basis of the experimental results obtained, it may be concluded that the relationship between ovule viability and the days after the onset of full bloom at 5°C, 10°C and 15°C was approximately linear, whereas at 20°C it was quadratic.

Ovule viability in the field over two experimental years in all the evaluated cultivars was complete, amounting to 100%, since there was no year to year difference. Average daily temperatures during full bloom in all the evaluated cultivars ranged from 9.1°C (the lowest) in 'Wangenheims Fruhzwetsche' in the first year, to 13.0°C (the highest) in 'Požegača' in the following year (Table 1). In such temperature conditions, the ovule viability in all the evaluated cultivars was shown to be high during the 10 days from the onset of full bloom and was equivalent to the ovule viability of individual cultivars at the constant temperatures of 5°C, 10°C and 15°C, under
Table 1. Mean daily temperature in the field during full bloom of plum cultivars in two years

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>1986 Onset of full bloom</th>
<th>End of full bloom</th>
<th>Mean daily temperature</th>
<th>1987 Onset of full bloom</th>
<th>End of full bloom</th>
<th>Mean daily temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Čačanska Rana’</td>
<td>9 April</td>
<td>19 April</td>
<td>10.6°C</td>
<td>21 April</td>
<td>1 May</td>
<td>10.7°C</td>
</tr>
<tr>
<td>‘Čačanska Najbolja’</td>
<td>9 April</td>
<td>19 April</td>
<td>10.6°C</td>
<td>20 April</td>
<td>30 April</td>
<td>10.7°C</td>
</tr>
<tr>
<td>‘Čačanska Lepotica’</td>
<td>9 April</td>
<td>21 April</td>
<td>10.6°C</td>
<td>21 April</td>
<td>1 May</td>
<td>10.7°C</td>
</tr>
<tr>
<td>‘Wangenheims Frühzwetsche’</td>
<td>11 April</td>
<td>21 April</td>
<td>12.2°C</td>
<td>25 April</td>
<td>5 May</td>
<td>13.0°C</td>
</tr>
<tr>
<td>‘Požegača’</td>
<td>15 April</td>
<td>25 April</td>
<td>9.1°C</td>
<td>26 April</td>
<td>6 May</td>
<td>11.2°C</td>
</tr>
</tbody>
</table>

Discussion

This paper presents data of ovule viability in five plum cultivars at four constant temperatures of 5°C, 10°C, 15°C and 20°C in laboratory, and under field conditions. Ovule viability, receptive period of the stigma and time required for the pollen tube to reach the ovules, present the major factors decisive for the longevity of E.P.P. These factors are the function of physiological and environmental conditions of the fruit tree (Williams, 1970). Interdependence of these factors was found in sour cherry at different constant temperatures, under laboratory conditions (Cerović & Ružić, 1992a,b). A number of results related to the evaluation of ovule viability, i.e. embryo sacs in fruit trees, have been published previously. Thus, ovule viability in cherries is shorter than in plums (Stösser & Anvari, 1990). However, ovule viability in some sour cherry cultivars ranged between day 3 and day 6 from the onset of full bloom, after which intense fluorescence occurred in all the remaining ovules (Anvari & Stösser, 1978b). Similar data were obtained with some sweet cherry cultivars, in which ovule longevity ranged from 4 to 5 days (Tonutti, Ramina, Cossio & Bargioni, 1991). Ovule longevity may even be shorter, e.g. in some apricot cultivars with a larger number of degenerated embryo sacs, it may only occur until day 2 from the onset of full bloom (Eaton, 1959). Contrary to these data, in pear cv. ‘Agua de Aranjuez’, viable embryo sacs in unpollinated flowers were observed even after the twelfth day of full bloom (Herrero & Gascon, 1987).

Climatic conditions, especially temperature, may have a limiting effect on the ovule viability. The evaluation of fluorescence in ovules, as an indicator of the loss of their viability in five plum cultivars, indicated that ovule viability at three constant temperatures: 5°C, 10°C and 15°C is high, i.e. it is similar to values under field conditions. These constant temperatures under laboratory conditions may approximate to mean daily temperatures under field conditions and are common to full bloom of the mentioned plum cultivars. In the conditions of northwestern Europe, temperature during full bloom in some plum cultivars may strongly affect irregular yields (Keulemans & Van Laer, 1987). Under such conditions, it was observed that the velocity of pollen tube growth was regulated by temperature differences during full bloom, suggesting that temperature is a decisive factor governing yield (Keulemans, 1984). It was also observed that low temperatures resulted in slower pollen tube growth or its cessation in some plum cultivars, thus pollen tubes cannot reach ovules before their degeneration (Stösser & Anvari, 1990; Thompson & Liu, 1973). At higher constant temperatures, e.g. at 15°C, pollen tubes in some plum cultivars reached ovules in 5 days (Jones, Stott & Williams, 1971), or in 8 days (Stott, Jefferies & Jago, 1973). Although the velocity of pollen tube growth was not studied in this paper, ovule viability during the 10 days of full bloom in all five plum cultivars should not be a limiting factor for successful fertilisation and fruit set in the field. Only if pollination was delayed would ovule viability become a limiting factor for fertilisation and fruit set (Stösser & Anvari, 1983). Thus, the pronounced high ovule viability in the plum cultivars under test resulted from their complete adaptability to lower temperature conditions, which prevail during flowering of these cultivars under Yugoslav conditions.

At the constant temperature of 20°C, all the plum cultivars exhibited a decline in regard to ovule viability. The loss of ovule viability indicates that all the plum cultivars are susceptible to constant temperature of 20°C. A similar effect of this, and higher temperatures, has been previously observed in sour cherry under laboratory conditions (Postweiler et al., 1985; Cerović & Ružić, 1992b). Although at this constant temperature pollen tubes in some plum cultivars required only 3 to 4 days to reach the ovules, in most cases they were not viable (Stösser & Anvari, 1990). In plum cv. ‘Victoria’ at 20°C, but also at lower temperatures, apart from fertilised ovules, many unfertilised ovules were observed in an advanced state of decay, with a shrivelled and collapsed nucellus (Jefferies, Brain, Stott & Belcher, 1982). In our study, cv. ‘Čačanska Rana’ showed the highest susceptibility, in relation to ovule viability at this constant temperature. Since this cultivar belongs to a partially
self-compatible group, it may be assumed that this high temperature during full bloom in some years, may have an effect on ovule viability, thus affecting fertilisation success and E.P.P., as found in sour cherry (Cerović & Ružić, 1992a; Cerović & Mićić, 1999).

The paper presents the study of ovule viability, i.e. the susceptibility in five plum cultivars under laboratory conditions to four constant temperatures of 5°C, 10°C, 15°C and 20°C and in the temperature conditions in the field. Thus, through simulation of temperature effects under laboratory conditions, it is possible to define precisely ovule viability in five plum cultivars, if any of the temperatures tested prevails in the field in some years. It is assumed that the viability of ovules is temperature-dependent, as is the case with pollen tube growth (Stösser & Anvari, 1982). For practical use, ovule viability requires the consideration of flower quality, the choice of an appropriate pollinator, pollination time, pollen intensity and pollen tube growth in the study, to define precisely the interdependence of temperature and these factors on fertilisation in plum. This would enable the development of an appropriate mathematical model for studying temperature effects on ovule viability, pollen-tube growth and fertilisation in plum cultivars, as reported for other plums (Jefferies et al., 1982) and sour cherries (Cerović, Mićić, Durić & Jevtić, 1998).

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References


