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# Morphophysiological peculiarities of productivity formation in columnar apple varieties

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**Abstract.** Differentiation of generative buds is one of the most important biological processes of plant transition from vegetative to generative state. This process is key to the problem of creating regular fruit-bearing and early-fruiting plantations. The article provides information on the organogenesis of buds in plants of columnar apple varieties in the Forest-Steppe of Ukraine, which allows establishing the features of this process in complex fruit formations of different ages, and the levels of their productivity and longevity. Research to study the organogenesis of different-age fruit formations of columnar apple varieties was conducted in the northern part of the Forest-Steppe of Ukraine during 2016–2020. The efficiency of realization the plants biological potential of all studied columnar apple varieties at III–IV and V–IX stages of organogenesis was high: the largest number of buds from their total number differentiated into generative on trees varieties 'Sparta', 'President', 'Bilosnizhka', 'Valuta' and 'Tantsivnytsia' (37–51%), the smallest in 'Favoryt' and 'Bolero'. The biggest number of flowers per one potentially generative bud was formed by plants of 'Tantsivnytsia' and 'Bilosnizhka' varieties. The lowest level of ovarian loss during the X stage of organogenesis was observed on plants of 'Valuta', 'President', and 'Tantsivnytsia' varieties (41–49%), and the highest - in 'Favoryt' variety (up to 83%). More effective realization of potential productivity at the XI stage of organogenesis occurred in plants of 'President', 'Valuta' and 'Tantsivnytsia' varieties; their trees on one potentially generative bud formed - 0.27–0.38 fruits. The coefficient of determination indicates that the influence of meteorological conditions of the year on the passage of III–IV stages of organogenesis is 46%; V–IX stages - 42%; Stage X - 17%; Stage XI - 24%.

**Key words:** columnar apple, productivity, organogenesis, differentiation of generative buds, fruit formations.

## INTRODUCTION

According to Isaeva (1989), the productivity of the apple tree is the totality of all organic matter formed during the process of photosynthesis, and in the economic sense, it is an integral part of biological productivity, which is realized in the form of fruit yield

(Zamorskyi, 2007). Isaeva (1974) recommends studying the productivity of apple trees in the process of their formation by analyzing the formation of rudimentary organs and their consistent development into vegetative and generative organs, which are elements of productivity (Rather et al., 2018; Vasylenko et al., 2021). It follows that productivity should be understood as the total number of elements formed on the fruit tree, and not just the fruit yield (El-Sabagh et al., 2012; Zuo et al., 2018; Mezhenskyj et al., 2020).

To periodize the process of shoot formation Isaeva (1989) proposed to modify the scheme Cooperman (1984). The modified scheme reveals the sequence of vegetative and generative organs formation, ie the process of productivity. The author considers the latter as the effectiveness of the realization of productivity potential at each stage of organogenesis. The effectiveness of realization is determined by the genotype of the variety and the conditions of its cultivation in a particular year (Isaeva, 1989; Palubicki et al., 2009; Kovalyshyna et al., 2020a; Kovalyshyna et al., 2020b).

Differentiation of generative buds is one of the most important biological processes of plant transition from vegetative to generative state (Duric et al., 1997; Mazurenko et al., 2020). It is the key in the problem of creating regularly fruitful and early fruiting plantations (Benko, 1967; Konarska, 2012). It is known that the laying and beginning of inflorescences and flowers formation in apple trees takes place in the previous year of the growing season. In the yield formation, III–V stages of organogenesis Isaeva (1989) considers critical, because the fate of the yield depends on the availability of conditions for the transition of potential fruiting points to the laying of flower buds. At the IV–V stages due to the formation of embryonic flowers is the laying of the elements of the yield, thus determining the total yield of the tree in the form of rudimentary flowers (Shevchuk et al., 2021).

The share of potential productivity, formed in the form of embryonic flowers (which successfully overwintered), is largely decided during pollination and fertilization (stage IX); it is at these stages that the possibility of realizing the potential in the fruit yield is largely determined (Havryliuk et al., 2019a). At the X–XII stages of organogenesis, the efficiency of flower realization in fruits is determined, the latter acquires a certain mass, which together determines the yield. But at the same time, there is a loss of productivity potential due to the reduction of flowers, ovaries, and fruits. The main reason for the reduction in productivity at the IX–XI stages of organogenesis in the apple tree is the excessive number of rudimentary flowers. The tree is not able to form fruit from all their number. At this time, potential productivity is lost, which is not provided with assimilates and therefore can not be realized (Havryliuk et al., 2019b). According to the nature of the reduction of productivity elements at the X–XII stages of organogenesis, apple cultivars Isaeva (1989) divided into several groups.

In studies conducted by Kondratenko (2013) in the conditions of Polissya and Forest-Steppe of Ukraine, the potential of productivity and efficiency of its realization in common apple varieties was determined. The scientist concluded that modern apple varieties of the domestic and foreign selection form a high potential for productivity; the most significant differences between varieties are found in III–IV and X–XII stages of organogenesis; the degree of reproductive elements reduction at the X stage of organogenesis depends on the variety and does not depend on the growing area; the potential of productivity is realized more effectively by the newest grades at cultivation on intensive technologies.

Scientific research hypothesis. The study of the productivity of columnar appletrees in the process of its formation, by analyzing the formation of rudimentary organs and their consistent development into vegetative and generative organs, which are elements of productivity, will establish the features of this process in complex fruit formations of different ages and levels of productivity and longevity. Knowing the level of influence of meteorological factors on the passage of II–XII stages of organogenesis, we can recommend more specific soil and climatic conditions for growing columnar varieties.

## MATERIALS AND METHODS

The research was performed during 2016–2020 at the Department of Horticulture named after Professor Volodymyr Levkovych Symyrenko of the National University of Life and Environmental Sciences of Ukraine. The experimental basis for the research was the planting of apple trees of the primary variety test at the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine.

The subject of research - 7 apple varieties of columnar type ('Tantsivnytsia', 'Sparta', 'Favoryt', 'Bilosnizhka' (Ukraine); 'President', 'Valuta' (Russia); 'Bolero' (England)) of three ecological and geographical groups of Ukrainian and foreign selection.

The object of research - the processes of potential and real (economic) productivity formation of apple trees varieties in the fruiting orchard.

The garden was laid in 2002 and 2010 according to the method of primary variety testing. Planting is not irrigated. Trees on rootstock 54–118 were planted according to the scheme of 4×1 m.

Meteorological data for the trial evaluation years were obtained at the Vantage Pro2 Plus weather station. The hydrothermal coefficient (SCC Selyanova) was calculated by dividing the amount of precipitation in mm by the sum of active temperatures of 10 °C and above for the period of growth and development of fruits. The obtained data were decreased 10 times.

**Instruments.** The buds were selected in five repetitions from complex flushes located in the middle part of the trunk of a certain age. Anatomical sections of buds 30–60 µm thick were made using a freezing microtome OmE. The obtained material was viewed using a microscope MBI-6 at a magnification of 90–180 times.

**Methods.** Quantitative evaluation of apple varieties productivity formation at III–IV stages of organogenesis and the effectiveness of their elements into the real yield (V–XI stages of organogenesis) was performed according to the method of Isaeva (1974). SEC (statistical evaluation coefficient) was calculated as the ratio of the number of reproductive elements at a certain stage of organogenesis to the number of buds that reached stage II of organogenesis.

**Description of the Experiment.** The number of elements of reproduction at certain stages of organogenesis was analyzed during the research. We also conducted a correlation analysis of the weather factors influence over 5 years on the actual number of potential fruiting points depending on the stage of organogenesis.

**Sample preparation:** The number of buds on the plant was calculated in early August. When the air temperature was less than 5 °C, the number of buds that differentiated into generative ones was counted. From the onset of subzero temperatures, anatomical and morphological analysis of the buds was performed under a microscope to determine their condition in the pre-winter period. During the IX stage of organogenesis (flowering), the total number of flowers on plants was counted. After the fall of the ovary in June (stage X of organogenesis), the number of ovaries that did not fall was counted. At the XI stage of organogenesis, the number of fruits was counted.

**Number of samples analyzed:** seven varieties of columnar type apple trees took part in the research. Each variety is represented by five plants (35 trees in total). The number of reproductive elements at certain stages of organogenesis was counted on each of the trees.

## Statistical analysis

Using correlation analysis, the strength of the connection between meteorological elements for the years of the field experiment and the number of elements of reproduction at a certain stage of organogenesis. The influence of the factor by the correlation coefficient is weak ≤ 0.29, moderate: 0.30–0.49, noticeable: 0.50–0.69, high: 0.70–0.89, very high: 0.90–0.99 (*LSD*: Least significantly difference at $P < 0.05$). Statistical processing was performed in Microsoft Excel 2016 in combination with XLSTAT.

## RESULTS AND DISCUSSION

The experimental site is located in the zone of the Western Forest-Steppe of Ukraine. The climate of the area is temperate continental and is characterized by mild winters and warm summers. The average annual temperature is 7.4 °C. The coldest month is January, with an average monthly temperature of minus 5.8 °C, and the warmest is July (19.6 °C). The first autumn frosts are observed from the second decade of October. Winter begins in the second decade of November. Permanent snow cover is established in December and disappears in the second decade of March. Thawing during the winter period (December-February) lasts an average of 40 days (repeated 8 to 10 times with a duration of 5 days). Spring frosts are likely by mid-May.

The growing season in fruit crops, according to long-term data, begins in the first decade of April. Active growth and development of fruit plants are observed in the third decade of April. The sum of active temperatures of 10 °C and above ($\Sigma_{akt}t \geq 10$ °C) is 2,850 °C, the number of days with a temperature of 10 °C and above - about 160. The average annual rainfall reaches 597 mm, most of which falls from April to October (400 mm). The wettest are the summer months - from June to August, an average of 68–81 mm of precipitation per month. In the period from November to March, about 230 mm of precipitation falls. The average number of days with precipitation is 160.

The soil of the experimental plot is dark gray podzolic medium loamy on carbonate loess, typical for the right-bank part of the Western Forest-Steppe. The humus content in the arable soil layer (0–40 cm) is 1.00–1.90%, the pH of the aqueous extract is 6.22–8.33.

During the III–IV stages of organogenesis due to the rudimentary flowers formation in the generative buds is the laying of potential yield elements of the tree (Buntsevich, 2014; Kohek et al., 2015). During this period, there is a loss of potential productivity in conventional varieties due to vegetative shoots, and in columnar (in most varieties) - vegetative buds on simple and complex shoots, which do not differentiate generative buds (buds with incomplete cycle of organogenesis). Kolomiets (1976) and Kobel (1984) investigated the dependence of generative buds differentiation on meteorological conditions (El Yaacoubi et al., 2020). According to the results of five-year experiments Isaeva (1989) found that this process begins earlier in warm and fairly dry summers than cold and rainy, but, in the opinion of the scientist, the difference in the timing of generative buds differentiation in different weather is insignificant and reaches 7–14 days. Kondratenko (2003) found a varietal difference in the timing of the beginning of generative buds' differentiation, in the degree of development of the latter in the pre-winter period, as well as in the timing and duration of IX–X stages of organogenesis for traditional apple genotypes. Information on the organogenesis of buds in plants of columnar apple cultivars, which would make it possible to establish the features of this process in complex shoot of different ages, is currently missing, as well as the levels of their productivity and longevity (Koutina et al., 2007; Yareshchenko et al., 2012).

Plants of the columnar varieties studied by us at the II stage of organogenesis formed, depending on the variety, 144–871 pcs. buds/tree. At the III–IV stages of organogenesis varieties differed in the efficiency of generative buds differentiation both among themselves and by years (Table 1).

**Table 1.** Efficiency of potential productivity realization by plants of columnar apple varieties at III–IV stages of organogenesis (SEC). IH NAAS, 2016–2019

| Stages of organo-genesis | Year | Variety | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Tantsivnytsia | Sparta | President | Valuta | Favoryt | Bilosnizhka | Bolero (c) |
| II | | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| III–IV | 2016 | 0.248 bc | 0.163 bc | 0.527 a | 0.548 a | 0.071 c | 0.425 a | 0.308 b |
| | 2017 | 0.922 a | 0.636 b | 0.496 b | 0.560 b | 0.337 c | 0.481 b | 0.288 c |
| | 2018 | 0.022 d | 0.205 b | 0.022 d | 0.021 d | 0.214 b | 0.341 a | 0.084 c |
| | 2019 | 0.852 a | 0.506 b | 0.422 bc | 0.482 b | 0.296 c | 0.346 bc | 0.243 c |
| Average for 4 years | | 0.511 a | 0.377 b | 0.367 b | 0.403 b | 0.230 c | 0.398 b | 0.231 c |

Means in lines with the different letter are highly significantly different according to the Fisher's test ($P \leq 0.05$).

On average, over the four years of the study, the biggest number of generative buds out of their total number was formed on 'Tantsivnytsia' trees (51%), the smallest - in 'Favoryt' and 'Bolero' (23%).

According to the coefficient of determination, the influence of the conditions of the year on the differentiation of generative buds on average for all varieties is 46%; of variety - 10%; interaction of conditions of the year and variety - 36%. Weather conditions had a strong influence on the differentiation of buds in the variety 'Tantsivnytsia', as evidenced by the correlation coefficient (Table 2).

**Table 2. C**orrelation coefficient between SEC and weather factors during III–IV organogenesis

| Variety | HTC | $\Sigma_{akt}t \geq$ 10 °C | Σ precipi-tation | Average daily air temperature |
|---|---|---|---|---|
| Tantsivnytsia | 0.95 | -0.80 | -0.95 | -0.91 |
| Sparta | 0.87 | -0.60 | -0.96 | -0.79 |
| President | 0.71 | -0.91 | -0.52 | -0.80 |
| Valuta | 0.78 | -0.96 | -0.60 | -0.87 |
| Favoryt | 0.52 | -0.16 | -0.69 | -0.40 |
| Bilosnizhka | 0.60 | -0.60 | -0.53 | -0.61 |
| Bolero (c) | 0.67 | -0.87 | -0.48 | -0.76 |

The influence of precipitation, $\Sigma_{akt}t \geq 10$ °C and average daily air temperature on the flower buds formation for varieties 'Favoryt' and 'Bilosnizhka' was weak and moderate. For the introduced varieties 'Bolero', 'President' and 'Valuta', as well as for domestic variety 'Sparta', a high negative correlation coefficient was established between the number of generative buds relative to their total number and $\Sigma_{akt}t \geq 10$ °C The influence of precipitation, $\Sigma_{akt}t \geq 10$ °C and average daily air temperature on the flower buds formation for varieties 'Favoryt' and 'Bilosnizhka' was weak and moderate. For the introduced varieties 'Bolero', 'President' and 'Valuta', as well as for domestic variety 'Sparta', a high negative correlation coefficient was established between the number of generative buds relative to their total number and $\Sigma_{akt}t \geq 10$ °C and the average daily air temperature and positive - with elevated HTC.

Thus, the differentiation of flower buds on plants of columnar varieties, one way or another, is influenced by certain meteorological factors (Lenz et al., 2016; Unterberger et al., 2018). Plants of introduced apple cultivars in the period of generative potential formation at III–IV stages of organogenesis are negatively affected by increase of level $\Sigma_{akt}t \geq 10$ °C and average daily air temperature, as well as decrease of HTC (hydrothermal coefficient). For most domestic varieties, the influence of these factors on the laying of flower buds is weak and moderate, which indicates a better adaptability of these varieties to the conditions of the Western Forest-Steppe of Ukraine.

Different numbers of flowers are formed in the generative buds of different types of fruit formations. On fruit twigs, terminal buds of shoots and shuts of ordinary varieties there are more of them (5–7 pcs.), And on fruiting shoots and in axillary buds of shoots - less (3–5). As a result, the participation of each type of fruit formations in the formation of productivity at stages IV–VIII of organogenesis changes. In the studied columnar varieties, the vast majority of fruit formations are represented by simple and complex shoots, in the generative buds of which, depending on the characteristics of the variety, 5 to 7 flowers were formed.

At the V stage of organogenesis of buds reduction of a considerable quantity of reproduction elements as a result of action on rudimentary flowers of low minus temperatures is possible (Amasino, 2010; Zuo et al., 2018; Xing et al., 2019). Kondratenko (2002) reports that in stages V–VIII during the winter-spring pruning of the crown in conventional varieties, more than 35% of generative buds are removed, ie the number of potential fruiting points is artificially reduced (Xing et al., 2016; Zhu et al., 2018). The realization of the productivity potential available in the form of flowers (IX stage of organogenesis) (Fig. 1) depends on the success of pollination and fertilization, which is influenced by meteorological conditions during flowering, as well as the presence of pollinating varieties and insects (Ryadnova & Eremin, 1964; Mir et al., 2016). In rainy and cool weather, pollination is complicated. Simultaneous and gradual flowering on the tree allows you to pollinate most of them (Srivastava et al., 2017). Thus, the asynchrony of flower bloom is one of the devices for the effective realization of the potential of productivity in the real yield.

On average, in 2017–2020, the largest number of formed flowers per potentially generative bud was observed in plants of varieties 'Tantsivnytsia' and 'Bilosnizhka', the smallest - in 'Favoryt' (Table 3).


**Figure 1.** Plants crown of studied apple varieties during mass flowering. IH NAAS, 2018: a – ‘President’; b – ‘Valuta’; c – ‘Favoryt’; d – ‘Bilosnizhka’; e – ‘Sparta’, f – ‘Tantsivnytsia’.

**Table 3.** The efficiency of the elements of reproduction implementation at the V–IX stages of organogenesis in plants of columnar varieties (SEC). IH NAAS, 2017–2020

| Stages of organo-genesis | Year | Variety | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Tantsivnytsia | Sparta | President | Valuta | Favoryt | Bilosnizhka | Bolero (c) |
| II | | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| V–IX | 2017 | 1.737 a | 0.475 a | 1.743 a | 2.033 a | 0.296 a | 2.034 a | 1.711a |
| | 2018 | 6.326 a | 3.178 bc | 2.480 cd | 2.799 bc | 1.684 cd | 3.368 b | 1.969 cd |
| | 2019 | 0.157 d | 1.025 b | 0.108 d | 0.105 d | 1.068 b | 2.387 a | 0.580 c |
| | 2020 | 5.865 a | 1.928 bc | 2.033 bc | 2.432 b | 1.479 c | 2.090 bc | 1.704 c |
| Average for 4 years | | 3.521 a | 1.651 b | 1.591 b | 1.842 b | 1.132 bc | 2.470 a | 1.491 b |

Means in lines with the different letter are highly significantly different according to the Fisher’s test ($P \leq 0.05$).

According to the coefficient of determination, the influence of meteorological factors of the year on the efficiency of the implementation of the reproduction elements at the V–IX stages of organogenesis was 42%; varietal characteristics - 16%; interaction of year conditions and varietal characteristics - 29%. In all studied varieties, with more rainfall during the V–IX stages, a smaller number of flowers was observed (Table 4); under conditions of higher average daily temperature and $\Sigma_{akt}t \geq 10$ °C their number per one potentially generative bud was higher.

**Table 4.** Correlation coefficient between SEC and weather factors during V–IX organogenesis

| Variety | HTC | $\Sigma_{akt}t \geq 10$ °C | Σ precipi-tation | Average daily air temperature |
|---|---|---|---|---|
| Tantsivnytsia | -0.96 | 0.84 | -0.89 | 0.75 |
| Sparta | -0.90 | 0.99 | -0.68 | 0.97 |
| President | -0.78 | 0.48 | -0.88 | 0.35 |
| Valuta | -0.75 | 0.45 | -0.85 | 0.32 |
| Favoryt | -0.60 | 0.84 | -0.31 | 0.88 |
| Bilosnizhka | -0.73 | 0.83 | -0.53 | 0.82 |
| Bolero (c) | -0.55 | 0.29 | -0.66 | 0.19 |

Therefore, under conditions of warm ($\Sigma_{akt}t \geq 10$ °C not less than 500) and not rainy spring (HTC not more than 0.50) during the IX stage of organogenesis in columnar apple varieties fully retains the number of flowers laid in the IV stage, which provides a high the level of realization of potential productivity.

At the X stage of organogenesis, the ovary increases in size, in the seed there is growth of endosperm and nucellus (Isaeva, 1989). There is also growth of unfertilized ovaries, which are reducing over the time. The duration of this process depends on the variety and is two to three weeks (Kuzin et al., 2018). At the XI stage the formation of the endosperm and embryo, as well as the hereditary size of the fetus determined for each variety is completed; depending on the conditions of a particular year, the size of the fruit may vary slightly. Thus, during the X–XI stages of organogenesis, along with yield formation due to a certain number of fruits and their average weight, there is a loss of its potential due to the reduction of ovaries and fruits. This process Gareev (1970), Kobel (1984) and others are divided into two periods.

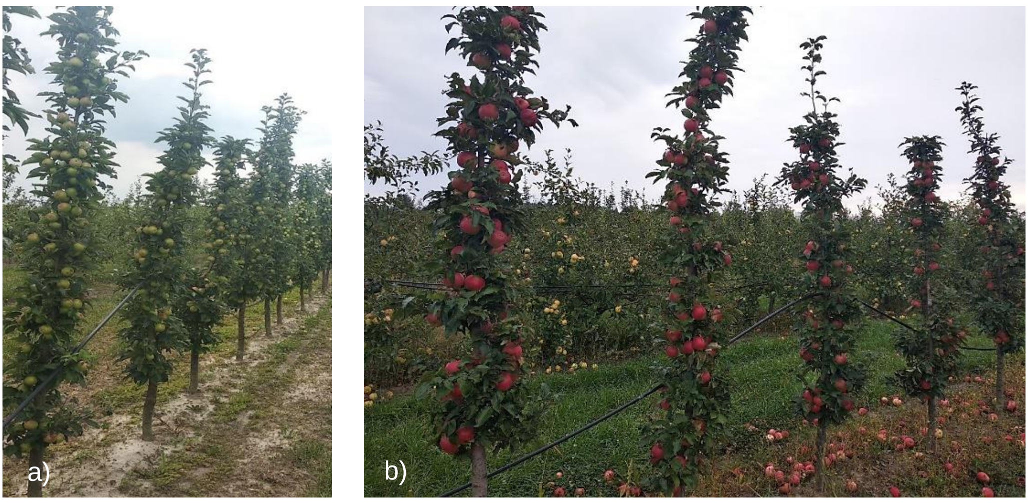


**Figure 2.** Plants of the 'Valuta' variety at a certain stage of organogenesis, IH NAAS, 2018: a – Stage X; b – Stage XI.

In general, on average in 2017–2020 studies, significantly lower levels of ovarian loss relative to control during stage X of organogenesis were observed in plants of Tantsivnytsia, ‘Valuta’ and ‘President’varieties (41–49%) (Fig. 2), the highest - in ‘Favoryt’, up to 83% (Table 5).

The coefficient of determination indicates that the influence of the year conditions on the passage of the X stage of organogenesis is 17%; varietal features - 13%; interaction between the conditions of the year and variety - 39%.

**Table 5.** The efficiency of the elements of reproduction implementation at the X stage of organogenesis in columnar varieties of apples (SEC). IH NAAS, 2017–2020

| Stages of organo-genesis | Year | Variety | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Tantsivnytsia | Sparta | President | Valuta | Favoryt | Bilosnizhka | Bolero (c) |
| II | | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| X | 2017 | 0.346 ab | 0.173 ab | 0.407 ab | 0.531 a | 0.090 b | 0.099 b | 0.274 ab |
| | 2018 | 0.694 ab | 0.148 bc | 0.892 a | 0.699 a | 0.176 bc | 0.152 bc | 0.377 bc |
| | 2019 | 0.035 c | 0.337 ab | 0.031 c | 0.046 a | 0.245 b | 0.349 a | 0.107 c |
| | 2020 | 0.572 a | 0.158 bc | 0.640 a | 0.567 a | 0.169 c | 0.124 c | 0.246 b |
| Average for 4 years | | 0.412 ab | 0.204 b | 0.492 a | 0.461 a | 0.170 b | 0.181 b | 0.251 b |

Means in lines with the different letter are highly significantly different according to the Fisher’s test ($P \leq 0.05$).

For the introduced varieties ‘Bolero’, ‘President’, ‘Valuta’ and domestic variety ‘Tantsivnytsia’, a negative correlation was found between the number of ovaries at the end of stage X of organogenesis and meteorological factors such as $\Sigma_{akt}t \geq 10$ °C and the amount of precipitation, and a significant positive correlation coefficient - with an average daily temperature (Table 6).

**Table 6.** Correlation coefficient between SEC and weather factors during the X stage of organogenesis

| Variety | HTC | $\Sigma_{akt}t \geq 10$ °C | Σ precipi-tation | Average daily air temperature |
|---|---|---|---|---|
| Tantsivnytsia | -0.59 | -0.43 | -0.51 | 0.65 |
| Sparta | 0.80 | 0.71 | 0.76 | -0.49 |
| President | -0.69 | -0.54 | -0.61 | 0.64 |
| Valuta | -0.81 | -0.69 | -0.75 | 0.60 |
| Favoryt | 0.81 | 0.90 | 0.87 | 0.06 |
| Bilosnizhka | 0.85 | 0.84 | 0.86 | -0.27 |
| Bolero (c) | -0.79 | -0.63 | -0.71 | 0.71 |

For the varieties ‘Sparta’, ‘Favoryt’ and ‘Bilosnizhka’ at the X stage of organogenesis, a high positive correlation coefficient was found between the amount of preserved ovary and $\Sigma_{akt}t \geq 10$ °C and the amount of precipitation. Therefore, by increasing the average daily air temperature in varieties ‘Tantsivnytsia’, ‘Bolero’, ‘President’ and ‘Valuta’ minimizes the reduction of reproductive elements at this stage of organogenesis. In the varirties ‘Sparta’, ‘Favoryt’ and ‘Bilosnizhka’, the reduction decreased with the decrease of $\Sigma_{akt}t \geq 10$ °C and the amount of precipitation. This means that under optimal meteorological conditions for a certain variety at the X stage of organogenesis, the coefficient of the reproduction elements realization will be much higher.

The highest level of potential productivity realization on average for 2017–2020 was observed in the varieties ‘President’, ‘Valuta’ and ‘Tantsivnytsia’; their trees per one potentially generative bud formed 0.27–0.38 fruit. The lowest level of potential productivity realization was found in plants of the control variety ‘Bolero’ (Table 7).

**Table 7.** Implementation of reproductive elements in trees of columnar apple varieties at the XI stage of organogenesis (SEC). IH NAAS, 2017–2020

| Stages of organo-genesis | Year | Variety | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Tantsivnytsia | Sparta | President | Valuta | Favoryt | Bilosnizhka | Bolero (c) |
| II | | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| XI | 2017 | 0.174 b | 0.063 b | 0.354 a | 0.325 a | 0.071 b | 0.119 b | 0.078 b |
| | 2018 | 0.611 a | 0.148 b | 0.770 a | 0.541 a | 0.158 b | 0.122 b | 0.155 b |
| | 2019 | 0.019 b | 0.169 a | 0.017 b | 0.024 b | 0.151 a | 0.172 a | 0.046 b |
| | 2020 | 0.290 c | 0.131 d | 0.376 b | 0.409 a | 0.140 d | 0.054 e | 0.103 d |
| Average for 4 years | | 0.273 a | 0.128 b | 0.379 a | 0.328 a | 0.130 b | 0.117 b | 0.095 b |

Means in lines with the different letter are highly significantly different according to the Fisher’s test ($P \leq 0.05$).

According to the coefficient of determination, the influence of the year conditions on the fruits reduction during the XI stage of organogenesis is 24%; varietal characteristics - 21%; interaction of conditions of the year and variety - 42%. In general, for almost all studied varieties it was found that the increase in useful ovaries, ie a decrease in fruit reduction during stage XI, is positively affected by an increase in the level of $\Sigma_{akt}t \geq 10$ °C, rainfall and average daily air temperature. A strong influence on the preservation of the reproductive potential of plants varieties ‘Tantsivnytsia’, ‘President’, ‘Valuta’ and ‘Bolero’ had an increase in the level of precipitation during the XI stage of organogenesis ($r$ = 0.85-0.98) (Table 8).

**Table 8.** Correlation coefficient between SEC and weather factors during the XI stage of organogenesis

| Variety | HTC | $\Sigma_{akt}t \geq$ 10 °C | Σ precipi-tation | Average daily air temperature |
|---|---|---|---|---|
| Tantsivnytsia | 0.87 | 0.74 | 0.87 | 0.47 |
| Sparta | 0.19 | 0.53 | 0.20 | 0.77 |
| President | 0.89 | 0.08 | 0.88 | 0.09 |
| Valuta | 0.86 | 0.58 | 0.85 | 0.20 |
| Favoryt | 0.38 | 0.65 | 0.39 | 0.80 |
| Bilosnizhka | -0.31 | -0.09 | -0.31 | 0.15 |
| Bolero (c) | 0.98 | 0.81 | 0.98 | 0.50 |

The fruit reduction decrease in all varieties, except for ‘Bilosnizhka’, was significantly and positively caused by an increase in $\Sigma_{akt}t \geq 10$ °C. The increase in the average daily air temperature contributed to the increase in the number of useful ovaries in the varieties ‘Sparta’ and ‘Favoryt’.

According to Kondratenko (2002), the realization rate of potential productivity less than 0.100 indicates serious violations in the technology of care for the variety, the inconsistency of the climatic zone of cultivation or the impact of adverse weather conditions in a particular year. The low realization rate was characteristic of the ‘Bolero’ variety, probably due to low rainfall ($r$ = 0.98) during the XI stage of organogenesis.

## CONCLUSIONS

In the conditions of the western Forest-Steppe of Ukraine, columnar apple cultivars react differently to environmental conditions at certain stages of organogenesis. The efficiency of differentiation of generative buds and the reduction of reproductive elements of columnar varieties are influenced in one way or another by meteorological factors. The efficiency of plants biological potential realization of all studied columnar apple varieties at III–IV and V–IX stages of organogenesis was high: the higgest number of buds from their total number differentiated into generative on trees varieties 'Sparta', 'President', 'Bilosnizhka', 'Valuta' and 'Tantsivnytsia' (37–51% ), the smallest in 'Favoryt' and 'Bolero'. The largest number of flowers per one potentially generative bud is formed by plants of varieties 'Tantsivnytsia' and 'Bilosnizhka'. The lowest level of ovarian loss during stage X of organogenesis was observed in plants varieties 'Valuta', 'President' and 'Tantsivnytsia' (41–49%), and the highest - in 'Favoryt' variety (up to 83%). More effective realization of potential productivity at the XI stage of organogenesis occurred in plants of varieties 'President', 'Valuta' and 'Tantsivnytsia'; their trees on one potentially generative bud formed - 0.27–0.38 fruits.

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