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Influence of budding height and method on bi-axis young apple trees (cv. 'Florina')

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Abstract. The article presents the results of the research on the influence of budding height and the method of bi-axis formation on quality indicators of young bi-axis apple trees of 'Florina' cultivar on B.118 rootstock in conditions of fruit trees nursery of educational and production department of Uman NUH. Budding with chip was made at the period of late July and early August at a height of 10 and 20 cm (the control). The formation of two axes was made with the help of budding in two ways: budding with one bud with pinching of a shoot at a height of 10 cm (the control); budding with one bud with pinching of a shoot at a height of 20 cm, budding with two buds that are opposite set, and budding with two buds that are alternate set and have a shift on a rootstock axis up to 5 cm due to each other.
The maximum trunk diameter was observed in young bi-axis apple trees that have alternate and opposite ways of budding with the help of two buds at a height of 10 cm above ground level. The reduction of the budding height up to 10 cm above ground level did not affect the height of the young bi-axis apple trees, though it had a significant effect on axis elongation. It was defined that one-dimensional formation of both axes occurred with the even distribution of length and number of branches on each were observed on young apple trees that had opposite budding with two buds at the above ground level height of 10 cm. The largest number of differentiated generative buds was observed on young trees that had opposite budding with two buds at the above ground level height of 10 and 20 cm.

Key words: Bibaum, bi-axis apple trees (*Malus domestica* Borkh.), budding height, flower buds, nursery, quality.

INTRODUCTION

The high quality of planting material is one of the main requirements for the creation of fast producing and high yielding plantations (Green, 1991; Lawes et al., 1997). For an intensive orchard, planting material with a trunk diameter of at least 14 mm and a formed crown is required. The crowned young trees with formed generative buds ensure fruiting already in the first year after planting (Gudarowska & Szewczuk, 2004).

The Italian company 'Vivai Mazzoni' developed and introduced Bibaum® young trees. Young trees of this type formed in the nursery have one-dimensional formation of both axes occurred in height and in diameter. Each axis has three or four branches about 15–20 cm long with differentiated generative buds (Musacchi, 2007). It was defined that

among the advantages of bi-axis young trees, compared to the traditional single-axis ones, are the predisposition better generative formations and increasing the total phytomass by 35% (Van Hooijdonk et al., 2015), higher potential for fruiting in orchard (Ma et al., 2020).

The formation of two developed leaders reduces the height of trees (Dallabetta et al., 2014) and increases the number of shoots (Lezzer et al., 2022). One of the main advantages of the planar bi-axis crown shape is its suitability for creating a narrow fruit wall, which involves reducing the row spacing and increasing the number of leaders per hectare. Bi-axis training also reducing fruiting shoot mutual shading and vegetative growth compared to single-axis in young apple trees (Yang et al., 2021).

The planar shape of the crown makes it possible to mechanise the processes of pruning and thinning (Musacchi & Greene, 2017), as well as to introduce computer vision technologies for assessing the condition of plantations and robotic harvesting (Mavridou et al., 2019). By reducing the height of the trees, the hail net is not damaged, and manual pruning and harvesting is facilitated.

Stefano Musacchi (2007) also points to the following advantages of the bi-axis training: easier control over growth processes as a result of a special distribution of gibberellins; better light interception; uniformity of fruits in size and color in all parts of the crown.

Despite the availability of young bi-axis apple trees, the agrotechnical aspects of growing this planting material have not been sufficiently studied. Therefore, for the adoption of a bi-axis training system for high-density apple orchards, it is necessary to develop effective technologies for growing planting material of appropriate quality, which determines the relevance of this problem and the need for special research.

The purpose of the experiment was to determine the influence of budding height and method on young bi-axis apple trees quality in growing conditions of Ukraine.

MATERIALS AND METHODS

We carried the research during 2016–2019 in conditions of fruit trees nursery of educational and production department of Uman NUH.

The object of our research was the process of cultivation of bi-axis apple trees of one-year period of growing of 'Florina' cultivar on B.118 rootstock. The 'Florina' cultivar was chosen for its disease resistance and the B.118 rootstock for its frost and drought resistance. This is in line with a sustainable approach to planting material growing.

The climate of the region is temperate continental with unstable humidity and uneven rainfall. The soil of the experimental plot is Chernozem (WRB: CH) with a heavy loamy granulometric composition and a low humus content (2.64%) in the topsoil.

In the first nursery field the trees were planted in order north-south according to 1.5×0.33 m scheme of trees planting. Chip budding was made at the end of July - at the beginning of August at a height of 10 and 20 cm (the control). The bi-axis formation was made by means of such types of budding: one bud with shoot pinching at a height of 10 cm (the control), one bud with shoot pinching at a height of 20 cm, two opposite set buds, and two alternate set buds and have a shift on a rootstock axis up to 5 cm due to each other (Fig. 1).

During the formation the individual axes of the young tree were oriented along the row and, for the convenience of calculation and analysis of indicators, they were given the conditional names ‘axis-1’ (oriented to the north) and ‘axis-2’ (oriented to the south).

Four-fold trial replication was applied, variants were placed with randomized replication - 25 plants in each plot. The main records and observations were made using a generally-accepted technique (Kondratenko & Bublyk, 1996).

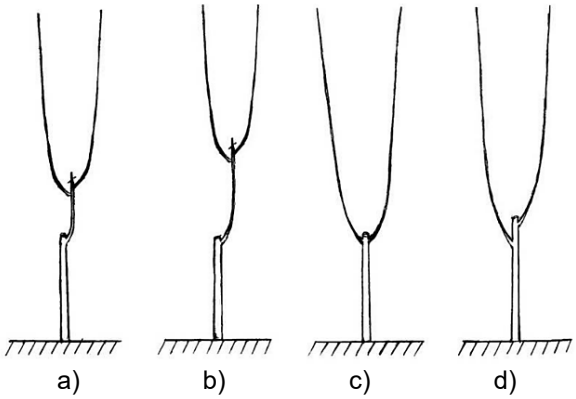

Figure 1. Methods of bi-axis formation: a – one-bud budding with shoot pinching at a height of 10 cm (the control); b – one-bud budding with shoot pinching at a height of 20 cm; c – two-bud opposite budding; d –two-bud alternate budding.

At the end of the vegetation season (20–25 October), the diameter of the rootstock part of trunk was determined with a caliper at a height of 10 cm from the root collar in two mutually perpendicular directions. The length of the conductors was determined by a measuring tape from the base of the shoot to the top of the apical bud. The height of the trees was determined by a measuring tape from the soil level to the apical bud on the highest leader. The diameter of the leaders was measured with a caliper at a height of 40 cm from the soil surface in two mutually perpendicular directions. The length of the branches in the crown was measured with a measuring tape from the base of the branch to the top of the apical bud. Only branches longer than 5 cm were included in the total length of branches in the crown. The average length of branches was calculated by dividing the total length of branches by their number. The number of lateral branches was counted for each tree.

All data were analysed by analysis of variance using Microsoft Excel and Statistica 6.1. Means separation was by Duncan's Multiple Range test at $P < 0.05$.

RESULTS AND DISCUSSION

It is well known that the quality of planting material significantly affects the productivity of fruit plantations (Green, 1991). As a result of the research, it was established that the best quality young trees were obtained in the variant with two-bud opposite budding at a height of 10 cm above ground level (Tables 1, 2).

The trunk diameter is one of the most important biometric indicators of the growth of the aerial part, which determines the quality of the planting material. The maximum trunk diameter which prevailed over the control by 19 and 21% was observed in young bi-axis apple trees with two-bud opposite and alternate budding at a height of 10-cm above ground level (Table 1).

Table 1. Qualitative indicators of young bi-axis apple trees due to the budding height level and method of formation of two axes

Budding height level, cm	Method of formation of two axes by means of budding	Diameter, mm	Diameter of axis, mm		Length of axis, cm		Height, cm
			axis–1	axis–2	axis–1	axis–2	
10	One bud with shoot pinching at a height of 10 cm	15.5 b*	10.2 b	9.3 d	118 c	112 c	131 d
	One bud with shoot pinching at a height of 20 cm	15.8 b	10.4 b	9.6 d	116 cd	109 cd	137 c
	Two buds opposite placed	17.1 a	11.1 a	11.3 b	143 a	145 a	152 a
	Two buds alternate placed	17.4 a	10.8 a	11.9 a	140 a	141 a	152 a
20	One bud with shoot pinching at a height of 10 cm (the control)	14.3 c	9.6 c	9.2 d	111 de	108 cd	136 c
	One bud with shoot pinching at a height of 20 cm	14.5 c	9.7 c	9.0 d	110 e	104 d	141 b
	Two buds opposite placed	16.1 b	10.3 b	10.5 c	138 ab	141 a	153 a
	Two buds alternate placed	15.7 b	10.0 bc	11.1 bc	134 b	133 b	149 a

* Due to Duncan's Multiple Range test means followed by different letters indicates significant difference at $P < 0.05$.

Table 2. Crown indicators of young bi-axis apple trees depending on the budding height and the method of formation of two axes

Budding height level, cm	Method of formation of *two axes by means of budding	Number of shoots			Length of shoot, cm
		axis–1	axis–2	total	
10	One bud with shoot pinching at a height of 10 cm	1.4 d*	1.3 d	2.7 c	26.5 a
	One bud with shoot pinching at a height of 20 cm	1.3 d	1.2 d	2.5 c	28.4 a
	Two buds opposite placed	3.1 a	3.2 b	6.3 a	18.4 b
	Two buds alternate placed	2.9 ab	3.6 a	6.5 a	18.5 b
20	One bud with shoot pinching at a height of 10 cm (the control)	1.5 d	1.3 d	2.8 c	27.5 a
	One bud with shoot pinching at a height of 20 cm	1.5 d	1.3 d	2.8 c	28.9 a
	Two buds opposite placed	2.6 b	2.7 c	5.3 b	19.3 b
	Two buds alternate placed	2.2 c	2.6 c	4.8 b	19.4 b

*For explanation, see Table 1.

In general the reduction of the height of budding favored the increase the trunk diameter by 8% (Fig. 2) which is consistent with the results of experiments by other scientists on single-axis young apple and pear trees (Blanco, 1988; Kviklys, 2006).

The maximum thickening of axis-1 by 16% and 13% and axis-2 by 22% and 29%, respectively was observed in young bi-axis apple trees that have alternate and opposite ways of budding with the help of two buds at a height of 10 cm above ground level, since their formation took place in the area of the trunk with the largest diameter.

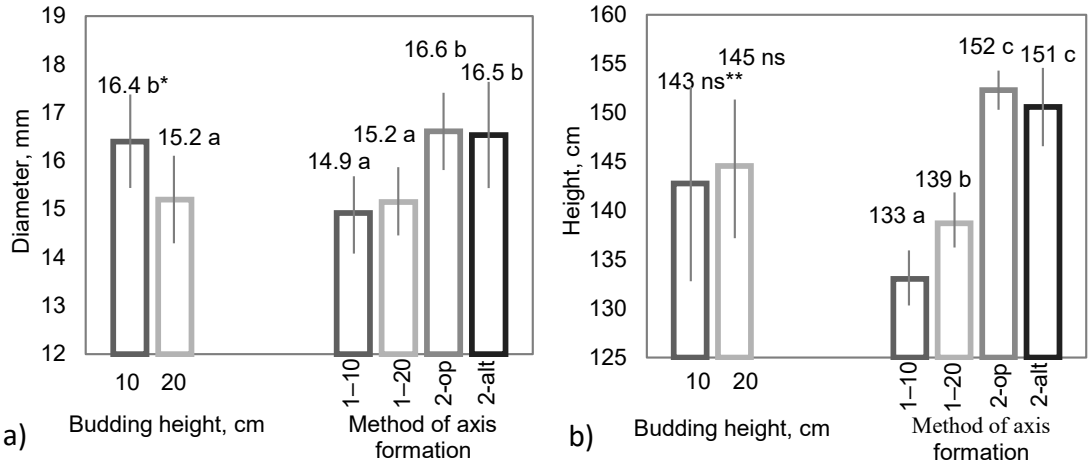

Figure 2. Average diameter (a) and height (b) of young bi-axis apple trees depending on budding height and method of axis formation: 1–10 – one-bud budding with shoot pinching at a height of 10 cm (the control); 1–20 – one-bud budding with shoot pinching at a height of 20 cm; 2-op – two-bud opposite budding; 2-alt –two-bud alternate budding.

*For explanation, see Table 1; **no significant difference.

Therefore, it can be assumed that reducing the height of budding in the nursery will have a positive long-term effect on the strength of the structure of bi-axis trees in the orchard.The process of apical growth of axis was mostly defined by method of their formation. Thus, it was established that two-bud opposite and alternate budding caused the elongation of axes which exceeded the control by 21–28% (axis–1) and 31–34% (axis–2).

This is obviously justified by the lack of intervention in the apical part of the shoot by pinching during the period of intensive growth, which is a necessary aspect for the bi-axis formation with one-bud budding.

For growing of young bi-axis apple trees, it is important to obtain two one-dimensional axes by thickness and length to ensure balanced growth and fruiting of trees after planting in orchard (Musacchi & Greene, 2017). In our research, according to the diameter one-dimensional axes were mostly defined on young apple trees with opposite set budding with the help of two buds. No significant difference was noted between the length of both axes in all options with two-bud budding, however, the axes differed the least in young trees cultivated by two-bud alternate budding.

An increase of rootstock share in the structure of young tree further increases the influence of the rootstock on the strength of tree growing (Rozsokha & Chygryn, 2002). In its turn S. J. Wertheim & A. D. Webster (2005) emphasize that increasing the length of the rootstock part in the structure of the young tree inhibits the transport of auxin from the root system to the apex and vice versa, which promotes crown formation.

In our research, the height of young trees with opposite and alternate two-bud budding reached maximum indicators and exceeded the control by 10–13%. The decrease of a budding height to 10 cm did not affect the height of the young tree, although it had a significant effect on the elongation of the axes. This is explained by the fact that the growth of axes in length when budding at a height of 10 cm did not exceed the length of the rootstock part of the above-ground structure of the young tree at a budding at a height of 20 cm. Therefore, it can be stated that reducing the influence of rootstock B.118 by decreasing the height of budding to 10 cm did not cause excessive growth of young bi-axis apple trees of 'Florina' cultivar.

Opposite two-bud budding at a 10 cm height level above ground caused the development of one-dimensional crown that had three short branches that were about 18 cm length on each axis (Table 2). Although two-bud alternate budding at a height of 10 cm caused the obtaining of the largest number of branches, it did not ensure an even distribution of the length and number of branches on both axes of the young tree.

The number and length of branches did not differ significantly in variants with one-bud budding. In its turn, opposite and alternate two-bud budding caused a decrease in the length of the branches by 30% compared to the control, which can be justified by the formation of their larger number under the mentioned conditions (Fig. 3).

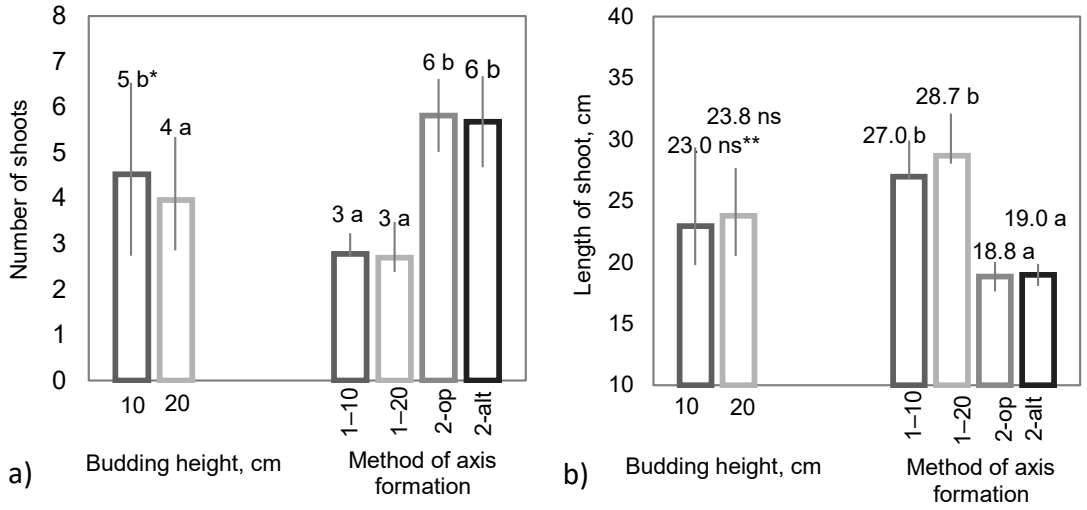

Figure 3. Average number (a) and length (b) of shoots of young bi-axis apple trees depending on budding height and method of axis formation: 1–10 – one-bud budding with shoot pinching at a height of 10 cm (the control); 1–20 – one-bud budding with shoot pinching at a height of 20 cm; 2-op – two-bud opposite budding; 2-alt –two-bud alternate budding.

*For explanation, see Table 1; **no significant difference.

Differentiation of generative buds in fruit crops begins already in the second half of the growing season. It is known that the first morphological changes in the buds of an apple tree appear from July to August (Friedrich et al., 1986). This means that the division of buds into vegetative and generative can be carried out in the year of young trees obtaining.

It was found that the researched elements of the technology of growing of young bi-axis apple trees had a significant influence on the formation of generative buds. The most generative formations were observed in young trees with two-bud opposite budding at a height of 10 and 20 cm, which exceeded the control by 70 and 66% respectively (Fig. 4). The indicator value in young trees with two-bud alternate budding at a height of 10 and 20 cm exceeded the control by 56 and 49% respectively. The increase of pinching height to 20 cm in young trees with one-bud budding at a 20-cm height above ground level resulted in a 6% reduction in the number of generative buds.

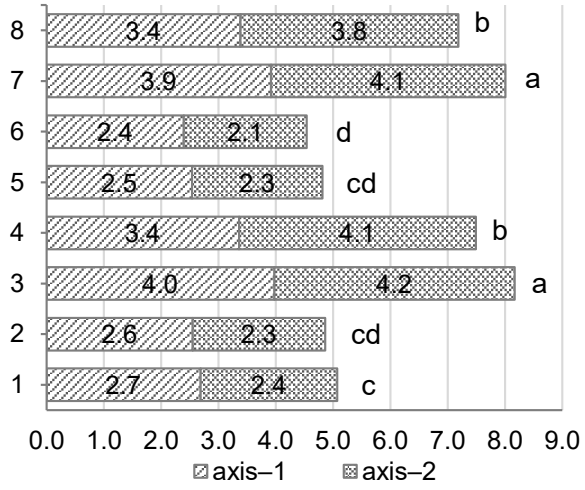

Figure 4. The number of generative formations on young bi-axis apple trees depending on the height of budding and the method of bi-axis formation: 1 – one-bud budding at a height of 10 cm with subsequent shoot pinching when it reaches a length of 10 cm; 2 – one-bud budding at a height of 10 cm with subsequent shoot pinching when it reaches a length of 20 cm; 3 – two-bud opposite budding at a height of 10 cm; 4 – two-bud alternate budding at a height of 10 cm; 5 – one-bud budding at a height of 20 cm with subsequent shoot pinching when it reaches a length of 10 cm (the control); 6 – one-bud budding at a height of 20 cm with subsequent shoot pinching when it reaches a length of 20 cm; 7 – two-bud opposite budding at a height of 20 cm; 8 – two-bud alternate budding at a height of 20 cm.

The increase of the number of generative buds by 1 and 5% respectively was noted when the height of budding is reduced to 10 cm above ground level in young trees with one-bud budding and subsequent shoot pinching of the grafted cultivar when it reaches a length of 10 and 20 cm.

In general, planting material cultivated by means of two-bud budding formed 60% more generative formations than that cultivated by means of one-bud budding.It can be explained by better quality indicators of young apple trees with two-bud budding (Tables 1, 2).

In the variants with one-bud budding, the increase of pinching height of the shoot of the grafted variety led to a 5% reduction of the quantity of fruiting formations. Though, the height of the young trees in these variants was greater. The reduction of a height of budding contributed to the not significant, but substantial increase of the quantity of generative buds by 5%.

It was found that the the optimal qualitative parameters of young bi-axis apple trees are provided by opposite two-bud budding at a height of 10 cm above the ground, which is likely to have a positive effect on the early fruit production in the orchard and should be tested in the following research. In addition, the effect of budding height and method on bi-axis young apple trees should be investigated on other apple cultivars and rootstocks in the nursery and afterwards in the orchard.

CONCLUSIONS

1. The reduction of the height of budding to 10 cm above ground level with two buds of 'Florina' cultivar on rootstock B.118 contributes to the formation of axes in the part of the trunk with a larger diameter, which improves the strength of the structure and improves the quality indicators of one-year bi-axis apple trees.

2. The use of two-bud opposite budding at a 10 cm height above ground level ensures the most one-dimensional formation of both axes with an even distribution of the length and number of branches on each.

3. Growing of young trees with two-bud opposite budding at a height of 10 and 20 cm creates conditions for the formation of a larger quantity of differentiated generative buds. This indicates the probable high potential of the planting material for fruiting in orchard.

4. Recommendations for commercial producers of planting material: in order to obtain high-quality and balanced bi-axis apple trees of one-year period of growing of 'Florina' cultivar on B.118 rootstock, budding should be carried out with two buds opposite set at a height of 10 cm above ground level.

5. The present research is limited to one cultivar and rootstock and it would be appropriate to investigate the effect of budding height and the method method of axis formation on other apple cultivar/rootstock combinations. There is also a need for further research into the influence of factors on the productivity of bi-axis apple trees after planting in the orchard.

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