Improvement of tree growth technology in weakly growing grafting points of apple tree (*Malus mill*)

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Abstract. This article studies the technology of growing seedlings of different varieties of apples at vegetatively propagated low-growing M-IX and medium-sized MM109 grafting points and provides scientifically based data. Grafting the upper-grafted bud by removing the wooden part resulted in a significant increase in its grip. When apple varieties were grafted to M-IX grafting point without removal of the wood part, the total amount of preserved upper-grafted buds ranged from 76% to 80% by variety, while in the experimental variant of grafting without wood, this figure ranged from 85% to 95% and observed to vary in this interval. When the bud graft is made to the root collar of the grafting point, this figure does not exceed 61.7-68.6% by variety. When the bud was grafted 10 cm above the root collar, it was found to be in the range of 67.5 to 75.9%, respectively.

1 Introduction

Scientific research is underway to further improve intensive orchards in the world's leading seed-growing countries. For this purpose, selection work is being carried out to create resistant grafting points suitable for the soil climate of the place. Apple “M” and “MM” series grafting points have been created, which can be used as a promising weak-growing grafting point suitable for intensive gardens, and they are widely used in intensive garden construction [1, 2].

Vinnikov [1] studied the effectiveness of grafting under the scalpel and bark on May 20 and summer bud grafting on July 29. According to a two-year follow-up, the rapid growth of the rod and leaves was higher when grafted under the bark than with other grafting methods. The dependence of tree pruning and shaping methods on the growth, development, and yield of the Golden Delicious and Fuji varieties of apples grown at low-growing M-IX and medium-sized MM106 vegetatively propagated grafting points has been studied and scientifically substantiated [3, 4].

Experimental material is presented on the results of studying the distribution patterns of spur apple varieties grafted on a weakly growing clonal apple stock M9. Studies have established that prior to the entry into the productive period, the placement schemes did not have a significant effect on the development of young apple trees with the formations we

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used. Beginning at the age of 5–6, the influence of this factor manifests itself significantly in the thickening of the crown of trees. During this period, to maintain a stable volume of the crown and the level of its illumination, it is necessary to combine thinning of shoots, combining with moderate shortening of large branches. In order to increase the yield of plantings, the Starcrimson apple variety should be placed with a 4x1 meter scheme, Golden Delicious - 4x1.5 meters [5, 6].

According to Islamov [4], in Uzbekistan it is recommended to graft the seeds in July-August. During these periods, the physiological activity status of cambium cells of grafting point and upper-grafted plant branches is high, and at this time the separation of the grafting point bark from the wood also poses no difficulty.

Namozov provided data on research for 2015, different in strength of growth of vegetatively propagated apple rootstocks, occulated on intensive apple varieties Renet Simirenko, Starcrimson, Golden Delicious, and Borovinka Tashkent and Korean [2, 5-7]. The data obtained allow us to draw the following conclusions that intensive apple trees, already in the nursery, developed successfully on the dwarf M9 rootstock, more slowly compared to the average tall rootstocks. The establishment of intensive orchards requires the production of well-developed seedlings, which, after transplanting into a permanent growing area, have a limited crown habit [8-12]. Such a morphological feature of the aboveground part allows placing a large number of plants on a unit of the garden area, which subsequently ensures higher yields in comparison with the extensive technology of apple growing quality can only be obtained by using well-developed rootstocks.

Namozov et al. provided information on the main indicators of productivity, growth and development of local and introduced apple varieties growing in the grasslands of Tashkent region. According to the productivity of the species, promising local and introduced varieties such as Julie Red, Red Atlas, Fairy Red Apple, Double Red Gares, Segledi, George Kav, and Khojeni have been distinguished [2, 5-7].

2 Materials and methods

In the experiment, clone grafting points of vegetatively propagated apples were planted in late autumn on a 70x20 cm scheme. In each variant, 200 plants were planted in four rows and the total area of the experiment was 224 m^2. Apple varieties to grafting points were grafted in the second decade of August. Weak-growing grafting points M-IX and MM109 were used as the object of study, and Golden Delicious, Starcrimson, Jonathan and Renet Simirenko varieties of apples were used as upper-grafted. The experiment was conducted in the following scheme:

1. Leaving the wood under the bud during grafting - control;
2. Removal of wood under the bud when grafting the bud.

One week after bud grafting, the number of buds caught and killed in late autumn, early spring, and at the end of the growing season, seedling emergence and their quality were calculated. The experiment was performed in 4 repetitions.

The experiments were carried out according to the recommendations and methods developed by Buriev et al. [5], "Methods of calculations and phenological observations in experiments with fruit and berry plants" and Ostroukhova's "Guidelines for growing seedlings of fruit and berry crops" [8-10]. Statistical analysis of the results of the study was performed in Excel 2010 and Statistica 7.0 for Windows computer programs, with a confidence interval of 0.95% by the method of Dospekhov [11, 12].

3 Results and discussion

There are many methods of grafting fruit plants, and the only opinion expressed by the researchers is that bud grafting is the most effective and reliable among them.

It should be noted that in most nursery areas no serious attention is paid to the wooden part of the bud cut for grafting in order to increase labor productivity, the number of buds per worker per day, and almost always placed under the grafting point bark with this wood. It should be noted that the wood of this cut upper-grafted bud will certainly die after it is separated from the parent twig, and the bud will become a barrier in the way of nutrients coming from the grafting point plant. This can lead to a slight reduction in nutrients coming from the upper-grafted booth.

Based on this scientific hypothesis, we conducted a study to study the effect of subcutaneous wood in the grafting of Golden Delicious, Starcrimson, Jonathan, and Renet Simirenko varieties on grafting points M-IX and MM109 for weak growth of apples (see Fig. 1).

Fig. 1. Interior of the upper-grafted apple buds, where the cut wood layer was left and removed for grafting.

Our experiments to study the effect of sub-bud woody layer on adherence have shown that grafting the upper-grafted bud with removal of the woody layer part resulted in a significant increase in its adherence. Consequently, when apple varieties were grafted to M-IX grafting point without removing the wood part, the total amount of preserved upper-grafted buds ranged from 76% to 80% by variety, while in the experimental variant grafted without wood, this figure ranged from 85% to 95%. The highest yield was 96% in the King David variety of apple.

The lowest adhesion of the buds was recorded in the generally accepted method, in the variant where the bud was grafted without removing the wood.

The data in the table show that the removal of the subcutaneous woody layer during the bud grafting operation resulted in a significant increase in their toughness. This was confirmed by an initial examination of the upper-grafted buds. The number of dead buds in them was 3–6% higher than in the experimental option.

The above trend in the retention of up-grafted buds was also maintained when grafting them to the MM109 grafting point. Consequently, the amount of buds killed in the autumn inspection in the experimental variants of the subcutaneous wood ranged from 8% to 12%, depending on the apple variety.

The Golden Delicious and Djonared varieties of apples were distinguished by the highest number of bud deaths, with the total number of bud deaths in these varieties being in the range of 10-12% by the time of this fall inspection.

The death of the buds was further exacerbated during the winter in experimental options where the bud wood was left. Uncomfortable winter conditions had a stronger negative impact on the buds, which had not yet held up well. At the same time, the extinction of the buds continued, and their maximum amount also reached 12-13% in these varieties. In general, the winter mortality of upper-grafted buds varied in the range of 8–13%, respectively, for apple varieties.

Grafting with the removal of the wood under the buds allowed recording a positive picture in their grip and preservation. Consequently, the amount of buds died before the autumn inspection when performing the bud grafting operation with wood removal ranged from 43 to 13% of the total number of buds grafted (see Table 1).

Table 1. Influence of subcutaneous woody layer on the adhesion of bud joints (2017-2019).

#	Varieties	Preservation of upper-grafted buds depending on the grafting method,%					
		Under bud woody layer was left – control			Under bud woody layer was removed		
		Bud died in an autumn inspection	Bud died in an spring inspection	Total preserved buds	Bud died in an autumn inspection	Bud died in an spring inspection	Total preserved buds
On M-IX grafting point							
1	Golden Delicious	12.1	14.2	73.7	7.1	6.7	86,2
2	Starcrimson	11.3	12.6	76.1	9.3	6.6	84,1
3	King David	10.3	10.7	79.0	3.8	2.7	93,5
4	Djonared	9.9	12.7	77.4	6.6	4.9	88,5
LSD_{05}				***2.2***			***2.7***
Sx, %				***1.0***			***1.3***
On MM109 grafting point							
5	Golden Delicious	10.4	12.1	77.5	8.1	5.3	86,6
6	Starcrimson	8.6	9.3	82.1	3.7	2.4	93,9
7	King David	12.4	13.7	73.9	4.6	2.6	92,8
8	Djonared	8.8	8.9	82.3	8.0	9.1	82,9
LSD_{05}				***2.3***			***2.9***
Sx, %				***1.1***			***1.5***

Removal of the lower bud woody layer ensured good adhesion of the upper-grafted buds, which allowed them to withstand the effects of adverse winter conditions well. Spring inspections showed that the amount of buds killed during the winter ranged from 1-6% at the M-IX grafting point. In this case, the Jonathan variety of apple with the highest preservation of the upper-grafted buds was distinguished, and the number of dead buds in this variety was only 2%.

The highest mortality of up-grafted buds was recorded in Golden Delicious and Starcrimson varieties. The amount of upper-grafted buds killed in them was around 6%. The remaining varieties ranked intermediate in terms of bud preservation.

The high degree of coupling of the up-grafted buds with the grafting point made it possible to observe the same landscape as above in the experimental variant grafted to the MM109 grafting point. At the same time, in King David and Starcrimson varieties up to 2% of the buds died during the winter. In other varieties, the figure was around 5-9%.

The high adhesion of up-grafted buds to the grafting point and their good preservation during the winter led to an increase in retention. This grafting method provided 83-95% adhesion on apple varieties. Vaccination with removal of subcutaneous woody layer also had a positive effect on the subsequent growth of seedlings and the yield of quality seedlings. Intensive development was observed in the grafted buds with the removal of the wood. This also had a significant effect on the fact that they would reach more than the standard size before the autumn digging and on the increase in the yield of seedlings. Selection of seedlings according to the state standard in the autumn digging showed that the yield of quality seedlings was higher in the options of bud grafting with the removal of the wood part. In seedlings grown by this method, the yield of quality seedlings was about 76-83% of the total obtained seedlings, while in the control variant of grafting, leaving the subcutaneous woody layer, the yield of seedlings was 69-74%.

A comparative analysis of the data in Fig. 2 shows that the highest yields of quality seedlings were higher at both grafting points in King David and Starcrimson varieties. Selection of seedlings into commercial varieties (I and II) on the basis of standard requirements in the autumn digging showed that in the experimental variant using this method of grafting reached up to 86% of varietal seedlings. At the same time, the amount of varietal seedlings in relation to the total mined seedlings in these varieties varied in the range of 83-84, 81-86%, respectively. The yield of the least varietal seedlings in this method of grafting was recorded in Golden Delicious and Djonared varieties, but it should be noted that even in this case the superiority of the control variant grafted without removing the bud woody layer was superior.

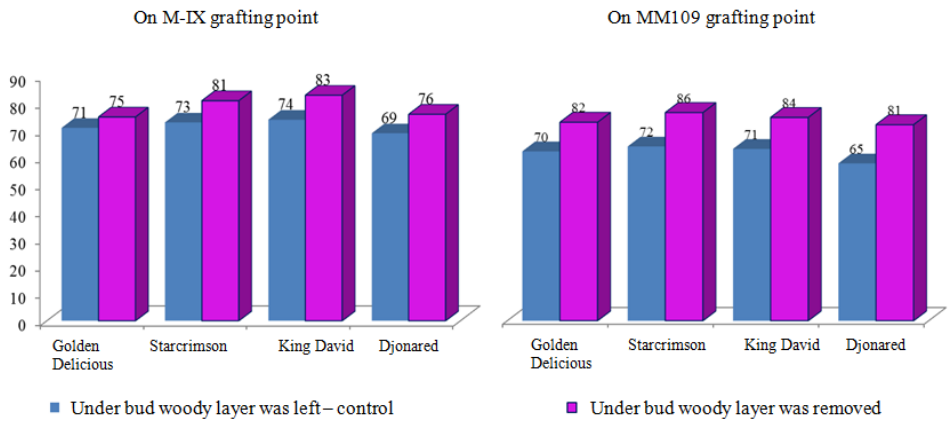

Fig. 2. Quality seedling yield, depending on the method of bud grafting of apple varieties, compared to the total harvested seedlings, in %.

In planting practice, there are many methods of agrotechnical measures that can be taken to increase the permeability of the bud graft. These include carrying out bud grafting at optimal times, adequate watering of upper-grafted and grafting point plants before and after grafting, and so on. It should be noted that the height of placement of the upper-grafted bud on the grafting point plant in bud grafting also plays an important role in its grip. We conducted experiments with apple varieties and grafting points used in our previous experiments to determine the maximum holding capacity of up-grafted buds and the height of grafts that could ensure their good preservation during the winter.

Experiments have shown that the height of grafting to the upper-grafted bud grafting point plant had a significant effect on its grip. Consequently, the highest mortality of upper-grafted buds before the initial (20 days after bud grafting) inspection period was observed when they were grafted (control) to the root collar of the grafting point plant. At the same time, the total number of upper-grafted buds killed in apple varieties grafted to the M-IX grafting point ranged from 14 to 18% by variety. The highest number of dead buds was recorded in the Djonared variety of apple (up to 18%). Grafting the up-grafted cultivar buds to a height of 5 cm from the root collar of the grafting point branch ensured that the buds were slightly better preserved. When up-grafted buds were grafted to the MIX grafting point rod at a height of 5 cm, the number of buds killed before the first observation period was the lowest in King David and Starcrimson varieties and was 9–10%, respectively. The highest number of dead buds was also observed in the Djonared variety of apple (up to 13%) in this experimental variant. When grafting upper-grafted buds slightly above the root collar of the grafting point (10 cm), their retention was almost indistinguishable from the previous experimental option (grafting at a height of 5 cm) and the amount of dead buds before autumn inspection was around 10-14% by cultivar (Table 2).

Experiments on the effect of positioning height on the grafting point plant of the upper-grafted bud have a tendency observed at the MM109 grafting point as well as at the MIX grafting point. Consequently, even in this grafting point type, the highest mortality of upper-grafted buds was observed when grafting them to the root collar.

Table 2. Influence of bud grafting height on uptake of up-grafted buds, 2017-2019.

#	Varieties	Upper-grafted bud preservation relative to grafting height, %								
		Grafted directly on roots - control			**Grafted above 5 cm from roots**			**Grafted above 10 cm from roots**		
		Bud died in an autumn inspection	**Bud died in an spring inspection**	**Total preserved buds**	**Bud died in an autumn inspection**	**Bud died in an spring inspection**	**Total preserved buds**	**Bud died in an autumn inspection**	**Bud died in an spring inspection**	**Total preserved buds**
On M-IX grafting point										
1	Golden Delicious	15.6	17.3	67.1	11.3	10.3	78.4	11.2	16.7	72.6
2	Starcrimson	14.9	16.7	68.4	9.8	9.4	80.8	11.7	15.0	73.3
3	King David	14.7	15.5	68.6	10.7	9.1	80.2	10.0	14.1	75.9
4	Djonared	18.2	20.1	61.7	12.3	10.0	77.7	14.2	18.3	67.5
LSD₀₅				***2.5***			***2.8***			***3.6***
Sx, %				***1.0***			***1.3***			***1.8***
On MM109 grafting point										
5	Golden Delicious	16.7	18.1	65.2	12.4	11.1	76.5	12.3	17.3	70.4
6	Starcrimson	14.1	16.9	69.0	9.9	10.6	79.5	11.4	17.5	71.1
7	King David	13.4	17.6	69.6	11.6	10.4	78.0	12.7	16.7	70.6
8	Djonared	19.7	22.3	58.0	13.3	12.7	74.0	14.8	20.1	65.1
LSD₀₅				***2.4***			***2.7***			***3.1***
Sx, %				***1.0***			***1.2***			***1.5***

Observation of the winter hardiness of the up-grafted buds made it possible to note that they had a clear advantage in the variant grafted to a height of 5 cm. An analysis of the table data shows that making the bud grafted height at ground level or raising it too high creates a negative state in their grip. Consequently, as recommended in a number of literatures, the implementation of bud grafting in the root collar part (control) of the grafting point resulted in many of their deaths. The death of buds grafted to the root collar was further increased, especially in harsh winter conditions. At the M-IX grafting point, the

number of buds killed the most in the winter was up to 20%. In the remaining varieties, this figure was in the range of 15-17%.

The main reason for the large number of buds grafted to the root collar was their damage due to excess moisture in the soil during autumn irrigation, as well as suffocation due to melted snow in winter. The re-freezing of melted snow water in the daytime and in the evening may also have had a negative effect on the buds' retention, in our opinion. Therefore, the death of the buds grafted to the root collar was at its highest in the winter.

It should be noted that when performing the grafting point height of the bud at a height of 10 cm from the root collar, although the amount of buds killed in the initial inspection (autumn) was not so large; their winter hardiness was much lower. In this case, too, the highest number of dead buds was in the Djonared variety, which accounted for 18%. In the remaining varieties, winter mortality of upper-grafted buds was around 14–16%. Placing the bud at a height of 10 cm can be attributed to the negative impact of winter frosty air flow, which, in our opinion, a lot of their winter loss, which occurs at a height of 10–20 cm above ground level.

Experiments have shown that 5 cm of bud grafting is the most preferred in terms of autumn-winter storage of buds and high grip. At this grafting height, the bud retention was up to 9% at the initial inspection and up to 11% at the spring inspection compared to the control option.

The difference in winter hardiness of up-grafted buds was also noted when grafting apple varieties to a weakly growing grafting point MM109, which propagated vegetatively. At this grafting point, too, the greatest loss of upper-grafted buds of apple varieties was recorded in the experimental variant, which was controlled in the winter and grafted at a height of 10 cm.

Depending on the height of grafting, the high degree of adhesion of the upper-grafted buds and their good preservation in the autumn-winter period allowed to note a clear difference in seedling emergence as well.

Autumn digging of seedlings and their sorting according to the state standard showed that the lowest yield of varietal seedlings was recorded in the control variant in which the buds were grafted to the root collar of the M-IX grafting point. In this variant, the yield of varietal seedlings relative to the total grafted buds did not exceed 63% and was around 55-63%, respectively, by variety.

The highest yield of varietal seedlings relative to the total number of grafted buds was recorded in the experimental variant grafted at a height of 5 cm. The highest seedling yield when grafted at this height was 81% in the Jonathan variety.

The low yield of seedlings at this grafting height was in the Renet Simirenko variety, which accounted for 72%.

An experimental variant of grafting at a height of 10 cm on the seedling output took an intermediate position. In this experimental variant, the seedling yield was slightly higher than the control variant, but lagged far behind the experimental variant, which was grafted at a height of 5 cm. The dependence of seedling yield on grafting height was also proven when grafting apple varieties to MM109 grafting point.

A comparative analysis of the image data above shows that the highest yield of quality seedlings was recorded at the MM109 grafting point when grafted to a height of 5 cm in both King David and Starcrimson varieties. The number of seedlings obtained in these varieties was 80% of the total number of grafted buds. Seedling yield from the remaining varieties at this grafting height was in the range of 70-77%.

The lowest yield of seedlings was also recorded in this grafting point type in the root-grafted variant (control). At the same time, the amount of seedlings in total compared to the total number of mined seedlings in these varieties was about 53-60%.

Vaccination to a height of 10 cm along the output of the seedling took an intermediate position at the grafting point MM109. In this experimental variant, the yield of varietal seedlings relative to the total grafted buds was around 60-68% (Fig. 3).

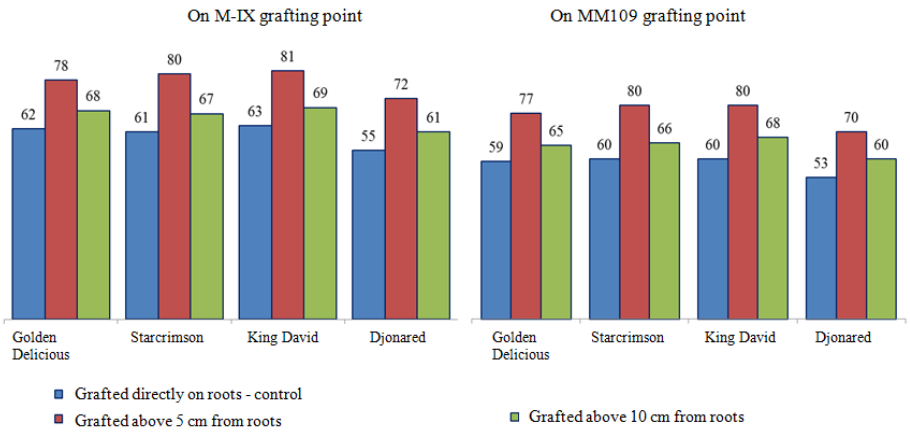

Fig. 3. Quality seedling yield, depending on the height of bud grafting of apple varieties, compared to the total harvested seedlings, in %.

4 Conclusions

1. Grafting the upper-grafted bud by removing the wooden part resulted in a significant increase in its grip. When apple varieties were grafted to the M-IX grafting point without removing the wood part, the total amount of preserved upper-grafted buds was 76% to 80% by variety, while in the experimental variant of grafting without wood, this figure ranged from 85% to 95%.

2. The yield of quality seedlings compared to the total grafted buds (57,142 pcs/ha, planting scheme 70 x 25 cm) when grafted with the removal of subcutaneous woody layer was 86% or 49,142 pcs/ha. When bud grafting was carried out without removal of subcutaneous woody layer, the yield of quality apple seedlings decreased by 72% and the yield of seedlings per hectare was 41,142. Such a difference in seedling output allows increasing the profitability of apple seed production on the basis of traditional technology from 557.4% to 647.1%.

3. The maximum holding capacity of up-grafted buds and the height of the graft, which can ensure their good preservation during the winter, is 5 cm from the root collar. The total number of buds caught at this graft height was 78.4% in the Golden Delicious variety, 80.8% in the Starcrimson variety, 80.2% in the Jonathan variety, and 77.7% in the spring inspection.

4. When the bud graft is made to the root collar of the grafting point, this figure does not exceed 61.7-68.6% by variety. When the bud was grafted 10 cm above the root collar, it ranged from 67.5 to 75.9%, respectively.

5. The main reason for the large number of deaths of buds grafted to the root collar was their damage due to excess moisture in the soil during autumn irrigation, as well as suffocation due to melted snow in winter. The re-freezing of melted snow water in the afternoon also has a negative effect on the budding hold.

6. When the buds are placed at a height of 10 cm, although their high preservation is observed until the autumn inspection, many deaths are observed during the winter

dormancy. This situation can be attributed to the negative impact of winter frosty air flow, which occurs at a height of 10–20 cm above ground level.

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