Dynamics of an apple tree yield after rejuvenation pruning

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Abstract. The studies were carried out in the apple orchard planted in 1987. The layout of trees was 7x5 m, the stock was vigorous (seedlings of cultivated varieties). In the first experiment, the influence of the crown cut on fruit yield was studied. The object of research was an apple tree of the Sinap Orlovsky variety. The following options were considered: 1. Without reduction in the crown height (control); 2. Cutting the tree height to 5.0-5.5 m; 3. Cutting the tree height to 4.0-4.5 m; 4. Cutting the tree height to 3.0-3.5 m. The trees were pruned in the spring of 2015. In the second experiment, perennial wood was removed and the yield was compared. The object of the study was an apple tree of the Antonovka Ordinary variety. The following options were considered: 1. Sanitary pruning (control); 2. Pruning for 3-4 year old wood; 3. Pruning for 5-6 year old wood; 4. Pruning for 7-8 year old wood. The trees were pruned in the spring of 2016. The experiments were repeated 4 times, each option used 6 trees, the placement of the plots was randomized. In the first experiment, on the sixth year, the highest yield (15.8 t/ha) was observed for the option with a crown cut to 4.0-4.5 m. This option also showed the highest total yield for 6 years (55.1 t/ha). In the second experiment for options with rejuvenation pruning, the total yield over 5 years exceeded the control option by 9.9-36.3%. The highest yield (52.2 t/ha) was obtained for the option with pruning for 5-6 year old wood.

1. Introduction

In central Russia, there are many apple orchards planted in the seventies and eighties of the last century. These gardens are characterized by rounded crowns, so acquire several significant disadvantages with age, which negatively affect their physiological state and the yield of trees [1, 2]. Most of these orchards are in disrepair, so the productivity and quality of fruits are low. However, with proper care, they can regularly bear fruit [3, 4]. The optimal physiological state can be maintained only with correct and regular pruning [5-7].

The main method of increasing the productivity of gardens of this type is to maintain growth processes [8-10]. The vast majority of studies aimed at controlling tree growth were focused on either genetic tools or cultural practices with the aerial parts of the tree and regulation of the root system [11-13]. Detailed pruning of trees is a rather laborious operation. It takes up to 60 man-days to perform a detailed pruning of 30-35-year-old trees per 1 hectare of garden [14] since it is required to make 35-90 thousand cuts [15]. The famous gardener N.P. Donskikh wrote in 1968 that detailed pruning, due to its labor intensity, is unacceptable, especially in old-growth stands [16].

Rejuvenation pruning, which includes cutting of the crown height and transferring of branches to perennial wood, is known to enhance growth processes and increase the productivity of fruit trees, including apple trees [17].
Rejuvenation of the apple tree crown on seedling rootstocks can cause disturbances in natural growth processes and lead to undesirable results in the form of the fruit tree's desire to restore the trimmed part of the tree, which is one of the most important biological properties of plants [18]. As a result of restorative growth, dormant buds awake on skeletal branches, from which “fatty” shoots grow, which can lead to even greater thickening of the crown and a decrease in the productivity of plantings.

The purpose of this work was to study the influence of the methods of rejuvenation of the crown of apple trees of the Sinap Orlovsky and Antonovka Ordinary varieties on the fruit yield.

2. Materials and methods
The studies were carried out in the apple orchard planted in 1987, the layout of trees was 7x5 m, the stock was vigorous (seedlings of cultivated varieties).

Experiment 1. The object of the study is an apple tree of the Sinap Orlovsky variety.

The following options were considered:
1. Without cutting the crown height (control);
2. Cutting the tree height to 5.0-5.5 m;
3. Cutting the tree height to 4.0-4.5 m;
4. Cutting the tree height to 3.0-3.5 m.

The experiments were repeated 4 times, each option used 6 trees, the placement of the plots was randomized. The trees were pruned in the spring of 2015.

Experiment 2. The object of the study is an apple tree of the Antonovka Ordinary variety.

The following options were considered:
1. Sanitary pruning (control);
2. Pruning for 3-4 year old wood;
3. Pruning for 5-6 year old wood;
4. Pruning for 7-8 year old wood.

The experiments were repeated 4 times, each option used 6 trees, the placement of the plots was randomized. The trees were pruned in the spring of 2016.

The fruit yield was accounted per a tree, by weighing with further conversion in t/ha. Sanitary pruning consisted of removing dry and broken branches annually. For the options with rejuvenation pruning, in the winter-spring period, vertically growing shoots more than 80 cm long were cut and less tall shoots were thinned out. In summer, vertically growing green shoots at the base of the skeletal branches were cut.

3. Results and discussion
Rejuvenation pruning had a significant impact on apple yield. In the first experiment (Table 1), crown rejuvenation was carried out in 2015.

Table 1. Yield of the Sinap Orlovsky apple tree as a function of the degree of crown height reduction

| Options                                | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | In total for 6 years |
|----------------------------------------|------|------|------|------|------|------|---------------------|
| Without cutting the crown height (control) | 3.6  | 10.4 | 1.3  | 9.7  | 0.4  | 7.1  | 32.1                |
| Cutting the tree height to 5.0-5.5 m    | 3.5  | 8.3  | 5.1  | 14.8 | 0.6  | 10.3 | 42.1                |
| Cutting the tree height to 4.0-4.5 m    | 2.8  | 6.7  | 6.0  | 22.1 | 0.7  | 15.8 | 55.1                |
| Cutting the tree height to 3.0-3.5 m    | 2.0  | 5.1  | 5.9  | 18.6 | 0.7  | 13.2 | 44.9                |
| HCP05                                   | 0.43 | 0.87 | 0.91 | 3.24 | 0.13 | 2.46 | 6.32                |

Pruning was carried out in a bad-harvest year, which led to a slight decrease in yield for options with the crown cutting. The differences between the options were only 0.8-1.6 t/ha. In the second year
after cutting the crown, the yield of fruits of the Sinap Orlovsky variety was lower than for the control. At the same time, the options with a heavier pruning of the crown showed a significantly lower yield of trees than the control. The smallest yield was observed for the option with a crown cut to a height of 3.0-3.5 m, which was two times less than for the control. When cutting the crown to a height of 4.0-4.5 m, the yield decreased by 20% and when cutting to 5.0-5.5 m it decreased by 30%.

In the third year after pruning, the degree of reduction in crown height did not affect the yield of trees. All options with crown rejuvenation had yield of 5.1-6.0 t/ha.

In 2018, i.e. in the fourth year after tree pruning, a higher yield was obtained for options with a crown cut to 4.0-4.5 m (22.1 t/ha) and 3.0-3.5 m (18.6 t/ha). The yield for the option with a crown cut to a height of 5.0-5.5 m was less by 25.7-49.3%, relative to the best options.

This tendency continued in the sixth year after the beginning of the experiment. The highest yield (15.8 t/ha) was registered for the third option with the crown cutting to a height of 4.0-4.5 m. This option showed the highest total yield for 6 years, which amounted to 55.1 t/ha. The option with the maximum crown reduction to a height of 3.0-3.5 m showed the total yield at the level of the option with the minimum crown reduction (5.0-5.5 m) - 44.9 and 42.1 t/ha, respectively.

Despite the decrease in yield for options with rejuvenation pruning in the first two years of fruiting, the total yield over six years for these options was 31.2-71.7% higher.

In the second experiment with the variety Antonovka, crown rejuvenation was carried out according to a different principle. In the experimental options, perennial wood of different ages was removed. Pruning was carried out in a productive year, which led to a significant decrease in the yield of pruned trees (Table 2).

Table 2. Productivity of the Antonovka apple tree depending on the degree of crown rejuvenation.

| Options                  | Yield of fruits, t/ha |
|--------------------------|-----------------------|
|                          | 2016 | 2017 | 2018 | 2019 | 2020 | In total for 5 years |
| Sanitary pruning (control) | 12.9 | 4.9  | 13.4 | 0.3  | 6.7  | 38.3                  |
| Pruning for 3-4 year old wood | 10.1 | 8.7  | 18.9 | 0.7  | 9.9  | 47.3                  |
| Pruning for 5-6 year old wood | 8.7  | 5.4  | 20.4 | 0.8  | 16.9 | 52.2                  |
| Pruning for 7-8 year old wood | 6.3  | 5.1  | 15.6 | 0.7  | 13.4 | 42.1                  |
| HCP05                    | 1.13 | 1.06 | 2.49 | 0.13 | 2.71 | 3.63                  |

Removal of perennial wood resulted in lower yields in the year of the experiment beginning. In 2016, the yield in the control option (sanitary pruning) was 12.9 t/ha, which is 27.7-204.8% more than for the options with rejuvenation pruning. The greatest decrease in yield was for the option with the removal of 7-8 years old wood.

In the second year after the rejuvenation pruning, the highest yield was obtained for the option with pruning for 3-4 years old wood, which exceeded the control option by 77.6%.

In the third year of fruiting (2018), the yield in options with pruning for 3-4 year old and 5-6 year old wood was significantly higher than in the control option. For the option with a stronger rejuvenation of the crown (pruning for 7-8 years old wood), the yield only reached the level of the control option.

In 2019, the weather conditions during the flowering period were unfavorable, which negatively affected the yield of the apple tree. The yield for the options was 0.3-0.8 t/ha. It was impossible to judge the effect of pruning on this indicator.

In the fifth year after pruning (2020), the control option was 1.48-2.52 times inferior to the options with rejuvenation pruning. The highest fruit yield was obtained for the option with pruning for 5-6 years old wood, which surpassed other options by 26.1-70.7%. For the option with pruning for 7-8 years old wood, the yield exceeded the control option only in the fifth year.

As in the first experiment, the total yield over 5 years, in options with rejuvenation pruning, exceeded the control option by 9.9-36.3%, while the highest yield was obtained for the option with pruning for 5-6 years old wood - 52.2 t/ha.
4. Conclusion
1. In the first two years after the rejuvenation pruning, the apple tree yield decreases relative to uncut trees, then it increases and exceeds the control option by 1.5-2.0 times.
2. Reducing the crown to a height of 4.0-4.5 m for the Sinap Orlovsky apple tree is the most effective way to increase yields.
3. Pruning of the Antonovka Ordinary apple tree with the removal of 5-6 year old branches already in the third year ensures the restoration of yield and maximum productivity.

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