*Bulgarian Journal of Agricultural Science, 25 (Suppl. 2) 2019*
*Agricultural Academy*

# Restocking cut in the birch forest with spruce crops under the canopy

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## Abstract

Gabdelkhakov, A. K., Sabirzyanov, I. G., Gabdrakhimov, K. M., Rakhmatullin, Z. Z. & Mullagaleev, I. A. (2019). Restocking cut in the birch forest with spruce crops under the canopy. *Bulgarian Journal of Agricultural Science, 25* (Suppl. 2), 59–65

The paper gives the analysis of subordinate spruce crops growing in birch forests with bush oak trees after different kind of restocking cuts. The cut intensity influences on the damage of 15-year old spruce crops. Thus, when 40-70% of forest stand is cut, the damage doesn't exceed 16%. During the clear cut when upper canopy is removed the damage reaches 45%.

During the first year after upper canopy cut, as it is shown in the paper, there is a decrease in height growth. Five years later after restocking cut the average height of the subordinate spruce crop not only reaches the level it was in the cut year, but also increases by 1.6-2.1 times. Partial or full removal of the upper stand canopy is in general good for spruce growth.

*Keywords:* restocking cut; spruce crops; height growth; conservation; forest plantations; spruce growth; canopy

## Introduction

Subordinate forest crops are created to increase the productivity, tolerance and esthetic appeal of disturbed and open stands. They are usually created in middle-aged stands without natural renewal with stand density not exceeding 0.5. Subordinate crops have some advantages. First of all, they contribute to the increase in the ecological productivity of forest stands and reinforce soil-protective stand features (Sultanova et al., 2018). In protective forests clean felling is impossible. There subordinate spruce crops are able to better realize the principle of forest use continuity (Pryakhin, 2002; Pommerening and Murphy, 2004; Konashova et al., 2018).

For a wide use of spruce advance planting as a way of reforestation special research of its growth at all the stages of sivicultural production is necessary (Khamaletdinov et al., 2018). This will contribute to solving the problem of productivity increase and improvement of forest qualitative composition.

The total forest area of the Republic of Bashkortostan is over 5.54 million hectares. On this territory there are big areas of subordinate spruce crop stands. Only during 1986-2004 over 34.0 million hectares of such crops were created. Unfortunately, nowadays they are not kept properly. Improper care of subordinate spruce crops or its lack increases the time lap of unfavorable conditions for this tree. This results in the decrease in its growing power and prospects to form economically valuable forest stands. Sometimes it even leads to their death (Sidorenkov, 2004; Hökkä and Mäkelä, 2014; Hökkä and Repola, 2018; Konôpka et al., 2018). Taking into account unfavorable influence of the upper canopy, special attention of intensive forestry should be paid to the restocking cuts. The cut intensity in forests where subordinate spruce crops are grown can be widely different depending on the crops state, age and goals of forming stands (Nilson and Lundqvist, 2001;Gspaltlet al., 2013).

Many scientists (Leemans, 1991;Hånell, 1993; Coates, 2000;Drobyshev and Nihlgård, 2000; Nilson and Lundqvist, 2001; Hanssen, 2003; Rubtsov and Deryugin, 2007; Valkonen et al., 2011;Eerikäinen et al., 2014; Hökkä and Mäkelä, 2014;

Deryugin, 2018; Cienciala et al., 2018; Hökkä and Repola, 2018) devoted their works to the study of the Norway spruce growth after different cuts both on cutover areas, in corridors and under the canopy. These works differ from each other in geography and results got. In view of this, at present there no standards on restocking cuts approved by the Federal Forestry Agency of Russia (Sidorenkov, 2001).

Taking into account all the above mentioned, the objective of our research is to study the state and growth of the advance planting of subordinate forest spruce crops in incomplete oak and birch stand after the restocking cut. Herewith, our tasks are to analyze subordinate spruce conservation, its state, the change of its annual height growth, and to estimate its growth depending on the way and intensity of the restocking cut.

## Method

To satisfy the objectives, we use common methods of forest inventory (Anuchin, 1982; Zagreyev et al., 1992; Verkhunov & Chernykh, 2007).

The subject of the research represents a permanent study area with six sections, which are types of the restocking cut. The experiment stipulated complete enumeration survey before and after the cut. The tally of subordinate Siberian spruce crops (*Picea obovata* Ledeb.) included the height measurement of a tree, its height increment during the last year ranging from 10 cm to half a meter before the cut and five years after it.

All the results of the studied stand measurements were processed with a personal computer using a standard Microsoft Excel package. In this case main methods of mathematical statistics were applied (Lakin, 1990).

The subject of the research is 65-year old summer stand of Silver birch (*Betula pendula* Roth.) with a sprouting English oak (*Quercus robur* L.) and 15-year old subordinate spruce crops. Furrow planting is used for the subordinate spruce crops, crop spacing being 4.5×0.7 m (3200 pcs/ha).

The sample plot is a flat area. The soils are grey, soddy and degraded, and loam in their mechanical composition.

The habitat type is C2 (fresh sudubrava) which belongs to the goutweed and bramble group of forests. Forestry ty-

**Table 1. Average taxation indices of a forest stand according to variants (before cutting/five years later after cutting)**

| Section number | Composition | Age, years | Height, m | Diameter, cm | Stem quantity pcs./ha | Sum of tree basal areas, $m^2$/ha | Stand volume, $m^3$/ha | Stand normality | Sampling, % | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | According to the stand volume | According to the sum of tree basal areas |
| 1 | 7B3O+L | 65 | 21 | 26 | 252 | 13.80 | 142 | 0.48 | 61 | 62 |
| | 10E | 15 | 1.9 | | 534 | | | | | |
| | 7B3O+L | 70 | 22 | 27 | 94 | 5.30 | 55 | 0.19 | | |
| | 10E | 20 | 3.0 | | 232 | | | | | |
| 2 | 8B2O | 65 | 24 | 30 | 174 | 12.83 | 138 | 0.42 | 100 | 100 |
| | 10S | 15 | 1.5 | | 961 | | | | | |
| | 10A | 5 | 2 | | | | 5 | | | |
| | 10S | 20 | 3.0 | | 343 | | | | | |
| 3 | 7B3O | 65 | 18 | 23 | 463 | 11.01 | 109 | 0.43 | 67 | 63 |
| | 10S | 15 | 2.0 | | 453 | | | | | |
| | 7O3B | 70 | 18 | 20 | 155 | 6.55 | 63 | 0.21 | | |
| | 10S | 20 | 2.9 | | 145 | | | | | |
| 4 | 7B3O | 65 | 23 | 29 | 244 | 15.92 | 168 | 0.54 | 73 | 70 |
| | 10S | 15 | 1.7 | | 504 | | | | | |
| | 10O | 70 | 20 | 26 | 67 | 3.60 | 35 | 0.11 | | |
| | 10S | 20 | 2.7 | | 481 | | | | | |
| 5 | 6O4B | 65 | 19 | 22 | 303 | 12.38 | 119 | 0.48 | 0 | 0 |
| | 10E | 15 | 1.7 | | 650 | | | | | |
| | 7O3B | 70 | 20 | 24 | 253 | 15.05 | 153 | 0.50 | | |
| | 10S | 20 | 2.7 | | 490 | | | | | |
| 6 | 6B4O | 65 | 21 | 26 | 219 | 11.85 | 121 | 0.42 | 38 | 41 |
| | 10S | 15 | 1.7 | | 502 | | | | | |
| | 10B | 70 | 23 | 34 | 98 | 8.86 | 96 | 0.31 | | |
| | 10S | 20 | 2.7 | | 474 | | | | | |

pological characteristic of the study plot planting is typical for the forests of the studied region (Konashova et al., 2018). Table 1 contains a short taxation characteristic of the forest stand according to the experiment variants. The data from the table show that the forest stand is of a mixed composition type, and it is equally presented by the English oak and European birch. Sections No. 1 and No.5 are partly populated with small-leafed linden (*Tilia cordata* Mill.). According to the experiment variants, the ratio in the composition varied from 8B2O to 6O4B.

The oak diameter according to the variants changed from 17 to 24 cm, for the birch - from 20 to 26 cm. The average diameter of the forest stand was 26 cm. The height of trees also varied: for the oak tree from 16.1 to 18.4 m and for the birch tree from 20 to 27 m. As for the density, it is of incomplete type for a 65 year-old forest stand. According to the experiment variants, it changed from 0.42 to 0.54. The average growing stock was 140 $m^3$/ha.

The restocking cut was carried out in different ways during the autumn and winter periods. The cut of the upper canopy by the corridor method was made in section No. 1. The cut was made on two rows with keeping uncut strips of the same width. In section No. 2 the upper canopy was cut completely, and in section No. 3 oak and birch trees were cut, the cut intensity making 65%. In sections No. 4 and No. 6 all birch and oak trees were cut (sampling intensity made 71% and 40% respectively). Section No. 5 was left untouched to be a control subject. Tree cutting, limbing and bucking were carried out in place with hand tools. Wood was transported in short logs without hauling.

## Results and Discussions

Statistical processing of the upper canopy according to the diameter was made. The processing date show a small positive skew (0.42) and platykurtos is (-0.29) when the variation coefficient is 35%.

Negative value of the platykurtosis speaks for the misshapen diameter distribution. Such distribution is typical for forest stands feeling the effect of selecting cuttings. In general, stem diameter distribution differs from the normal distribution law which is proved by the Kolmagorov-Smirnov test 0.104 and its value $p < 0.01$. This difference is stipulated by the different time of selective and sanitary cuttings which led to the increase in this value potential productivity.

Some changes of taxation stand indices took place five years later after the restocking cut. So, in the control section No. 5 there was natural increase in height and diameters of all forests elements (oak, birch and spruce trees). The total current increment was about 7 $m^3$ per/ha. It proves rather high level of forest growth conditions of the study plot. The change in the diameter and height in the section No.1 is not so significant. Here, the volume of growing stock even decreased after the corridor restocking cut as a result of unauthorized cuttings (several trees).

Rather interesting changes can be seen in section No. 2 where the cutting of the entire upper canopy was carried out. There is regeneration of oak, birch and aspen trees..The regeneration of the 2 m height aspen tree (*Populus tremula* L.) is of a group character. It occurs on the places where soils are damaged by machinery.

In section No. 3 there is also natural increase in height and diameter of oak and birch trees. The growing stock has also increased slightly (27 $m^3$ per/ha). In section No. 4 birch trees in the upper canopy were cut, but oak trees were untouched. Therefore, height and diameter increse is not significant there. The growing stock dicrease by 10 $m^{3/}$ ha as a result of windbreak and drying-out of oak samples.

In section No.6 oak trees in the upper canopy were cut, but birch trees were untouched. Here, the increase in height and diameter is more significant than in section No. 1. There are also windbreak birch samples, but they are much fewer. Moreover, birch trees contribute to high increment which results in the increase of growing stock by 20 $m^3$/ha after cutting.

The survival of the planted transplants depends on light admission, energy growth, ways and intensity of cuttings etc. (Fjeld, 1998; Metslaid et al., 2007; Surakka et al., 2011; Granhus, 2013; Bitkov, 2017). The conservation of subordinate spruce crops according to the sections is shown on Figure 1. With the reference to the above mentioned it can be seen that crop conservation before the restocking cut varies from

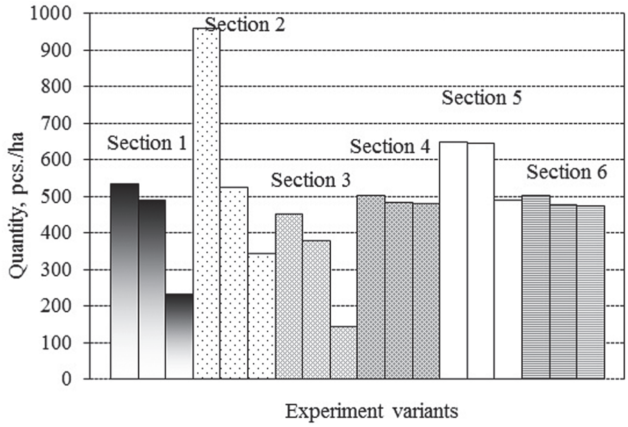


**Fig. 1. Conservation of subordinate spruce crops: left column – before cutting, right column – five years after cutting**

453 pcs/ha in section 3(14%) and to 960 pcs/ha in section 2 (30%). In other sections the crop quantity was approximately equal (500-600 pcs/ha). After the restocking cut, tree felling and transporting, the number of crops decreased (control section excepted).

In section No. 2 there was a maximum decrease where clear cut of the upper canopy was carried out. Sections No. 1 and No. 3 showed a low decrease. And in section No. 6 the number of crops slightly changed. Similar changes can be seen after five years of the cutting.

The height of spruce trees before the cutting varied averagely from 1.5 m in section No. 2 to 2.1 m in section No. 3 (Figure 2). The comparison of the average indices of height of subordinate crops revealed a significant difference (increase) in sections No. 1,2,5,6. In sections No. 3 and 4 there was external height increase. But the difference was not proved statistically ($t_{calc} < t_{st} = 1, 96$). The height of half spruce trees is from 1.5 m to 3.0 m. About 37% of trees have height from 0.5 to 1.5 m. There is significant spruce growth in all the sections of the study plot, including the control section (section 5), five years after the cutting. Almost all the indices of the height flattened out and vary from 2.7 m in the sections No. 4 and 6 to 3.0 m in the sections No. 2 and 5.

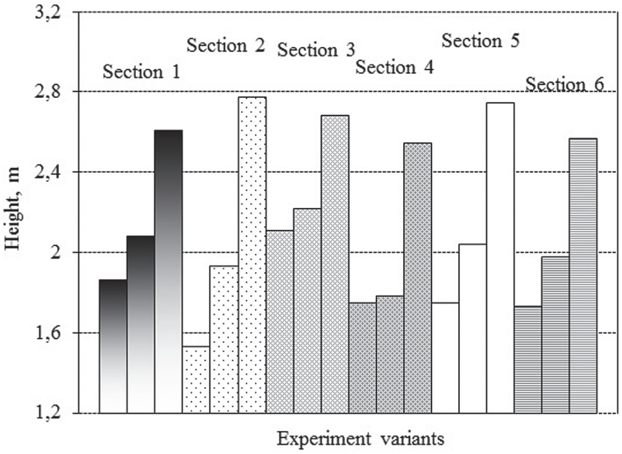


**Fig. 2. Average height indices of subordinate spruce crops according to the sections: left column-before cutting, middle column-a year after cutting, right column-five years after cutting**

The average height growth in the cutting year varied from 17 cm in section No. 3 to 24 cm in section No.2 (Figure 3). The height growth of almost 39% of spruce trees was less than 11 cm in a year, and 41 cm in a year for 6% of the trees (Table 2).During the first years after the upper canopy cutting there is some height growth slowdown resulting from

**Table 2. Ration of the quantity of crops under canopy depending on their height growth, %**

| Section number | Height growth during the last year, cm | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | over 11 | | | 11-20 | | | 21-30 | | | 31-40 | | | 41 and over | | |
| | Before cutting | A year after cutting | Five-years after cutting | Before-cutting | A year after cutting | Five-years after cutting | Before cutting | A year after cutting | Five-years after cutting | Befor-evutting | A year after cutting | Five-years after cutting | Before-cutting | A year after cutting | Five-years after cutting |
| 1 | 39.2 | 54.9 | 12.4 | 25.6 | 29.4 | 7.1 | 17.9 | 14.0 | 14.8 | 5.4 | 1.7 | 14.2 | 11.8 | 0.0 | 51.5 |
| 2 | 41.6 | 49.4 | 5.8 | 27.4 | 31.8 | 8.0 | 17.7 | 12.6 | 6.2 | 9.2 | 6.2 | 14.2 | 4.0 | 0.0 | 65.7 |
| 3 | 45.9 | 52.6 | 32.8 | 24.3 | 25.0 | 10.3 | 19.3 | 13.2 | 8.6 | 8.8 | 8.6 | 22.4 | 1.7 | 0.7 | 25.9 |
| 4 | 40.5 | 56.6 | 8.0 | 28.6 | 26.7 | 12.8 | 18.7 | 8.0 | 11.2 | 11.1 | 6.4 | 23.6 | 1.1 | 2.4 | 44.4 |
| 5 | 43.6 | 77.1 | 15.5 | 25.6 | 16.2 | 17.5 | 20.9 | 3.0 | 11.7 | 2.6 | 3.0 | 14.6 | 7.3 | 0.7 | 40.8 |
| 6 | 29.9 | 75.6 | 14.6 | 27.0 | 16.4 | 21.1 | 21.3 | 6.0 | 17.6 | 13.7 | 1.0 | 36.7 | 8.1 | 1.0 | 10.1 |
| Average indices | 40.1 | 61.0 | 14.9 | 26.4 | 24.3 | 12.8 | 19.3 | 9.4 | 11.7 | 8.5 | 4.5 | 20.9 | 5.7 | 0.8 | 39.7 |

the light regime changes and other ecological factors. As a consequence, the assimilative system adapts to the changed environmental conditions. A year after the cutting the height growth decreased in all experiment variants, including the control section: from 1 cm (section No. 3) to 8 cm (section No. 6). The decrease in height growth is statistically significant ($t_{calc} < t_{st}$), with the exception of section No. 3. Accordingly, there was a displacement of the number of crops with the lowest height growth: 61% less than 11 cm in a year and less than 1 % over 41 cm in a year.

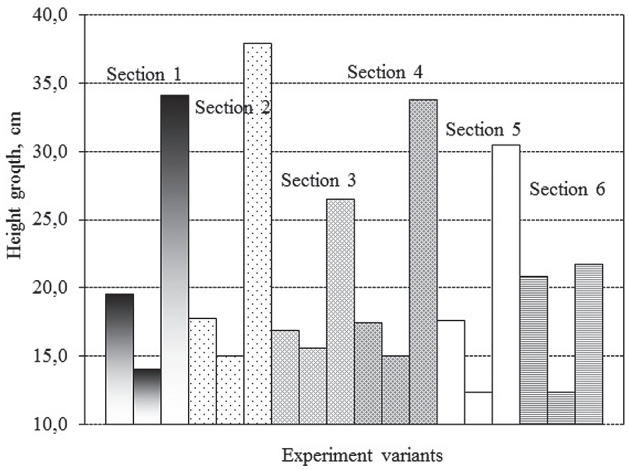


**Fig. 3. Average indices of height growth of subordinate spruce crops according to the sections: left column – before cutting, middle column – a year after cutting, right column – five years after cutting**

Five years after the cutting there was a significant height growth in comparison with the previous periods. The improvement of growing conditions influenced greatly on spruce trees height growth. Herewith, the section with the clear cutting of the upper canopy supersedes the others. The corridor section (section No. 1) in its turn supersedes the section with uniform shelter wood cutting (section No. 3). And the section under the oak tree canopy (section No. 4) prevails over the crops under the birch tree canopy (section No. 6). If restocking cut is not carried out, subordinate spruce trees will be less productive. In this context our research is coherent with the work of A.A. Deryugin (2018).

Five years after the restocking cutting spruce trees adapted to new conditions. This is proved by the ratio of the number of trees which showed high height growth. So, the share of the samples with the height growth over 41 cm in a year made averagely 40%. However there are some significant differences according to the variants. Thus, spruce trees with the maximum height growth grow mostly in section No. 2 (the clear cutting of the upper canopy). The section with corridor and uniform shelter wood cutting methods comes next.

## Conclusion

Significant thinning of the upper canopy as the result of the restocking cut doesn't guarantee high increase in the remaining part of the growing stock volume. Leaving of only one tree species in the composition of the upper canopy leads to the loss of forest stand tolerance. Thus, wind breakage and tree drying intensify especially for oak trees, not for birches. The implementation of aspen, linden and other trees in the section with the clear cutting leads to forming of complex forest stands (except birch and oak trees).

The conservation of subordinate spruce trees growing on the study plot during 20 years from the planting time was very low. In the year of the restocking cut it made about 19% and five years after the cutting it was 11%. The period after the upper canopy cutting is characterized by a fall in 1.7 times of the height growth in the section with clean oak cutting. In the section with the corridor cutting this index decreased in 1.4 times. In the control section there was also a decrease in the height growth in 1.5 times evidently influenced by climatic and other factors (Egorova, 1984; Cunningham et al., 2006; Drobyshev & Nihlgård, 2000). Five years after the restocking cut the average height growth of the subordinate spruce tree doesn't not only rebound to levels seen in the cutting year (section No. 6). It even increases in 1.6 times, the cutting intensity being 65%, and in 2.1 times in case when the clear cutting of the upper canopy is carried out. A full cutting of the upper canopy creates more favorable conditions for the height growth of the subordinate spruce trees. The rate of the damage of fifteen-year old crops is influenced by the cutting intensity. Thus, it doesn't exceed 16 % when from 40 to 70% of the forest stand is cut, the distance between the corridors being 4.5 cm in this case. At the same time, in case of the complete removal of the upper canopy (clear cutting) the damage rate reaches 45%.

Therefore, initially it is recommended to apply Malayan uniform systems for full upper canopy cutting of fifteen and twenty-year old subordinate spruce trees (the restocking and clear cutting to be applied with the conservation of the sapling). Most of the forest trees we studied belong to mature and over mature forest stands. In case if they were not subjected to timely restocking cuts, it is possible to carry out clear and two-stage alternate strip cuttings in exploitable forests to replace clear cuttings for protection reasons. This should be done in forests of the intended use because of the limit of the number of the clear cuttings. All the above mentioned contribute to the decrease in the loss connected with the light fright in strips left for the second cutting. High spruce wind blowing capacity can be neglected because of the young age. In general, the results of the research can be applied to develop recommendations for the restocking cutting of forest stands with subordinate spruce crops, and for the improvement of their growth with the use of new resource saving technologies.

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