BRIEF REPORTS

Seed Dispersal and Distribution of Silver Birch (*Betula pendula*) Naturally Regenerating Seedlings on Abandoned Agricultural Land at Forest Edges

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Evaluation of seed dispersal distance and natural regeneration of birch on abandoned agricultural land, and definition of the relationships between the distance from seed source and stand structure in order to find the best methods to get good natural regeneration have been studied. The regeneration was evaluated by measuring the naturally regenerating seedlings of birch within the circle sample plot.

Dispersal of birch seeds started in July and some part of the seeds remained on the trees when our observations were finished in September. Most of the birch seeds (2500 to 4000 seed per m^2) landed close to the forest edge at the distance approximately equal to the mean height of the birch stand. When moving apart from the forest edge, the number of seeds dispersed decreases unevenly.

The abundant natural regeneration occurs at distance of 5 to 7 m from the forest edge. The number of naturally regenerating birch seedlings was especially high up to 50 m from the forest edge (the number of birch seedlings on average exceeded 70 thousands of seedlings per ha, crowns of the seedlings were completely closed with crown cover ranging between 100 % to 250 %).

Most probably, the edge of the new birch stand will be at the distance of 110 m from the forest edge (the seed source). Further apart from the forest edge, only single groups of birch seedlings were regenerating. Small groups of birch seedlings were found as far as 170 m from the forest edge. However, the number of these groups was too little to form a new stand of appropriate productivity.

The spatial distribution of naturally regenerating seedlings was not uniform. There were many empty spots, the occurrence of which did not depend on the distance from the forest edge. Empty spots were also found close to the forest edge, where the number of dispersed seeds was largest. To obtain uniform natural regeneration over whole site, soil scarification prior to seed dispersal is needed.

Key words: natural regeneration, seedlings, seeds, Silver birch.

Introduction

Owing to more intensive agriculture, the area of abandoned agricultural land increased, basically, at the expense of infertile land. Afforestation of this abandoned land would be a good solution to diminish risk for soil erosion, improve ecological conditions and, at the same time, to obtain income from timber production. Afforestation is one of the main means to utilise abandoned agricultural land in Central and Western Europe.

In the course of the land reform, there is a possibility to improve the efficiency of landscape ecosystems as well as ecological conditions in the country. This need to improve the ecological conditions in the country is raised by the necessity (1) to afforest large areas of abandoned land, (2) to cope with negative effects of amelioration, building of roads, pollution and global climatic change to natural ecosystems in the country.

The targets for utilisation of abandoned land depend on agricultural and socio-economic policy. In most of the cases, the priority is set to find optimum combination of the ecological and economical values. Selection of appropriate tree species and use of genetically superior material would improve both ecological and economical values.

A naturally regenerating stand can be used for the following purposes (Wiersum 1984):

1) as a woody vegetation (to prevent erosion and etc.) or as a shelter for regeneration of other species,

2) as a stand for commercial purposes (other than short rotation),

3) short-rotation plantation.

Birch is among the most successfully naturally-regenerating pioneer tree species, which may be useful as a shelter for shade-tolerant species. However, birch may severely suppress new regeneration of the light demanding species. Nevertheless, it would still be worth to establish birch stands which may bring economical gain and improve ecological values.

Wind direction and strength

The distance of seed dispersal mainly depends on the speed and the direction of wind, which are very important factors to consider when assessing the possibilities for natural regeneration on abandoned agricultural land. In Lithuania, western and southern winds prevail (i.e. blowing from west and from south). North-eastern winds are blowing less often. During the warm period (May to October), western and south-western winds prevail (the probability is from 35 to 40 %) (Каушила 1983).

There are pronounced differences in the speed of wind at different time of the year. From May to September, western winds are strongest. Northern and north-eastern winds are weak all over the year.

According to Kaushyla (1983), in Lithuania the mean wind speed is 3.6 m/s. The highest mean wind speed is reaching 4.3 m/s in November and the lowest mean wind speed is 2.7 m/s in August. The minimum wind speed may be close to zero at any time of the year. The maximum wind speed used to be from 5 to 8 times greater and in gusts from 5 to 8 times greater than the mean wind speed. Namely, the very strong winds have the main effect on seed dispersal distance. In Lithuania, the winds often reach the speed of 15-17 m/s or, in gusts, may reach 22 to 24 or even 28 m/s. However, such extremely strong winds do not occur every year (Каушила 1983).

Birch seeds become mature in July and are dispersed up to the end of September (Kohlermann 1950). During this period, western winds prevail and there used to be 8 to 11 very calm days per month, the average wind speed is 2.7 to 3 m/s, mean maximum wind speed is 9.2 to 9.6 m/s (average for maximum wind speed over a period of time), the wind gusts are reaching 18 to 24 m/s and are less strong than in spring (Каушила 1983).

Forecasting the seed crop

The following factors are of major importance for success and quality of natural regeneration: (1) abundance of flowering, (2) genotypic composition of the seed stand, (3) quality of the seeds, especially, the genetic quality (more seeds from better genotypes).

According to Danusevicius (1991), it is considered years of abundant seed yield (seed years) as years during which more than 70 % of the trees in the stand are flowering. Genetic diversity of the seed crop produced during a seed year is high as it usually contains seed from more than 2/3 of the trees in the stand. During the years of weak seed yield, seed from only 10 to 15 % of the trees within the stand are available. In addition, variation in flowering abundance among individual trees within a stand shall be considered. Most often, the "wolf" trees used to be superior in flowering capacity (Danusevicius 1987 and 1991).

Several methods to forecast the years of abundant seed yield are available (Postanovlenije po lesosemenomu delu 1980, Spravocnik po lesosemenomu delu 1978, Danusevicius 1991). Owing to possible climatic change, forecast of seed yield based on the observations on occurrence of seed years in the past may often be misleading. The forecast of seed yield for a given tree species shall better be based on observations of abundance of flowering according to the Korcagin scale or the Kaper scale (Danusevicius 1991). The following shall be considered when planning the seed forecast: the seed source shall be in affinity to the regeneration site, the parental stand shall have reached the reproductive maturity.

According to Kohlermann (1950), the age of reproductive maturity of birch stands on open areas begin from 10-15, in stands – from 20-30 years. Abundant seed yield occurs in 2-3 years periods. One birch tree of pre-mature stands produced during the seed years 420 thous. seeds, or 140000 thous. of seed per 1 ha. This amount seeds may also be dispersed at the forest edge (Kohlermann 1950).

Material and methods

Studies on distance of seed dispersal were carried out close to the reproducing stands of birch. At the beginning of seed dispersal, study plots of 0.5 m² in size were established in each 15 m with 5 replication in backward direction from the forest border. The fallen birch seeds were recorded weekly. The study plots were distributed in East-West direction at distances of up to 110 m from the forest border. Seed recording was started at the beginning of July and lasted until September. Based on the data of observations at the agrometeorological stations, strength and direction of wind was evaluated during the period of seed dispersal.

Based on the data of the forest inventory, it was found that during the last decade, the largest areas

of self-regenerated Silver birch stands in the abandoned agricultural lands had formed five years ago (Lietuvos miškų ūkio statistika 2000). Therefore, the 5-year - old Silver birch stands were studied.

This study was performed in 2000. For this study, 12 abandoned agricultural areas being under self-regeneration stage and continguous to the Silver birch stands were chosen in the forest enterprises of Jonava and Kazlų Rūda. The study objects are situated on the same kind of Podzolic sandy soils. The soil moisture conditions and bulk density of the soil on all study objects are similar.

Spacing and distribution of trees in the self-regenerated abandoned agricultural lands were evaluated in the circle-shaped study blocks (experimental plots) of 100 m^2 in size. The study blocks were situated in all directions perpendicularly to the edge of seed origin. Close to these stands, the study blocks were situated every 25 metres in the perpendicular direction from the edge of them. In perpendicular direction, 5 to 8 circle-shaped study blocks were established, depending on the size of the area to be studied. In each abandoned area, 5 series of the circle-shaped study blocks were established every 50 metres in a lengthwise direction from the forest edge. In each abandoned area, depending on size, 25 to 40 study blocks were established. The size of abandoned areas varied from 2 to 3.5 ha. The total size of all study blocks (experimental plots) per abandoned area varied from 0.25 to 0.4 ha.

Each tree was evaluated entirely in the study blocks. The meansuration data for trees were evaluated by the adopted methods. Tree crown projection was measured in two directions as well.

The statistical analyses of data were performed by the MS Excel program. According to the statistical analyses of data, the results are presented graphically.

Results and discussion

Seed dispersal at the forest edge

In Lithuania, dispersal of Silver birch seeds usually starts in the middle of July (Danusevicius, 1991). The beginning of seed dispersal depends on climatic conditions. Favourable environment during pollination and seed development results in production of a larger number of seeds. It is unlikely, that the climatic conditions will be favourable for seed development during all the stages of the reproductive circle. This may explain variation in seed yield between different years.

Seed yield may also depend on soil fertility. Under the same climatic conditions, trees grown on rich soils yield twice as much seed as trees grown on poor soils (Gorzelak 1999).

There is a large variation in germination capacity among the seed lots collected in different years.

Percentage of empty seeds differs between the years and is usually ranging from 10 % to 30 % of the soils (Gorzelak 1999). Empty seeds are produced after self-pollination, which may occur more often in the lower part of the crown.

Seed dispersal distance depends on wind speed and height of the seed trees. When following down, the seeds are flying in spiral. Seeds of Silver birch are falling down at the speed 0,59 m/s (measured in the diagonal) (Kohlermann 1950). Then, on a calm day, the seeds dispersed at the height of 30 m should reach the ground in approximately 50 seconds. During these 50 seconds, the seeds may easily be blown away from the parental tree. Single seeds may fly over 200 m from the seed parent (Kolerman 1950).

A detailed study on dispersal of birch seeds at the forest edge was carried out. An open site adjacent to the 65-year-old birch stand in the Girelė forest district (Jonava forest enterprise) was chosen for this study. The birch stand was located at the western edge of the open site. In year 2000, there was an abundant seed yield in the birch stand. Pattern of the birch seed dispersal over the open site during the period from July to September, 2000 is shown in Figure. 1.

Dispersal of birch seeds started in July and some part of the seeds remained on the trees when our observations were finished in September. Therefore, the number of dispersed seeds may be larger than that presented in Figure. 1. Most of the birch seeds (2500 to 4000 seed per m^2) landed close to the forest edge at the distance approximately equal to the mean height of the birch stand. In some places at the very forest edge, the number of seeds was very large over 4000 seeds/m^2. When moving apart from the forest edge, the number of seeds dispersed is decreasing unevenly. In the 40-metre-wide belt 35 m from the forest edge, the number of dispersed seeds was from 500 to 1000 seeds per m^2. However, at two observation plots located 50 m from the forest edge, the number of seeds exceeded 1000 seeds per m^2. In the 35 metre-wide belt 75 m from the forest edge, the number of seed dispersed from July to September did not exceed 500 seeds per m^2. However, again, there were small plots with the number of seeds larger than 500 seeds per m^2. More than 100 m from the forest edge, the number of dispersed seeds did not exceed 100 seeds per m^2.

Though comparably a large amount of birch seeds are landing close to the parental stand, only a minor part of these seeds is germinating. Ground germination of birch seeds usually does not exceed 15 % (Suchockas, 2001). Due to unfavourable environment, such as heavy grass cover, not all of the sound seeds are

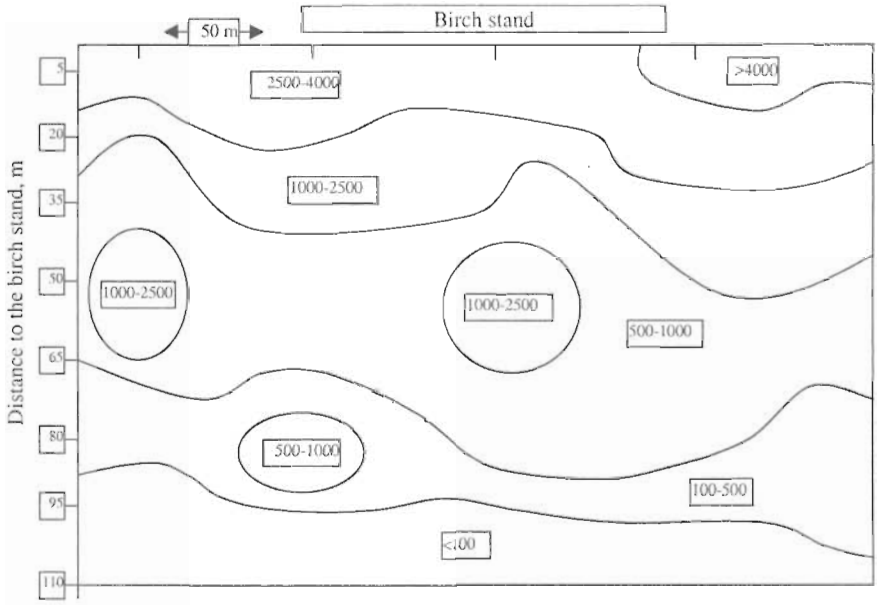

Figure 1. Pattern of birch seed dispersal over the open site during the period from July to September, 2000. The numbers on the axes show distance to the birch stand. The numbers on the plot show number of seeds found per m^2.

capable to germinate. Usually not more than 1% of birch seeds used to germinate on the sites with a heavy grass cover (Suchockas, 2001).

Spatial structure of naturally regenerating seedlings at the forest edge

The study on patterns of natural regeneration on abandoned agricultural land has revealed, that the spatial distribution of naturally regenerating seedlings is not uniform. Seeds of birch may be dispersed rather far from the seed source and even a single well-flowering tree may provide a sufficient number of seeds to cover a site of several hectares large.

Our study on natural regeneration on abandoned land has shown, that abundant natural regeneration occurs in at distances of 5 to 7 m from the forest edge. This may be explained by the negative effect of the seed trees on the regenerating seedlings at the very edge of the forest.

Variation in density of naturally regenerating seedlings of birch when moving apart from the forest edge

Seed yield in birch stands is greater than in other tree species stands. Thus, the number of birch seeds dispersed from the birch stand to the adjacent areas was much greater than that of seeds dispersed from the other tree species stands. In Lithuania, dispersal of birch seeds occurs in July and August. During this time, western winds prevail. Birch seeds are comparably light and, therefore, can be transferred over a long distance. In addition, wind gusts may lift and blow away the birch seeds which are already lying on the ground and are not swollen yet. Therefore, natural regeneration of birch seedlings is on-going fairly well to all directions from the parental stand. However, our study has revealed, that birch regeneration tends to be more abundant to the south of the parental stand.

Owing to a much larger number of the seeds dispersed, the density of naturally regenerating seedlings of birch was by far higher than that of other tree species. The negative effect of the forest edge for natural regeneration of birch was less than for natural regeneration of pine, i.e. the seeds of birch were successfully germinating already at distances of 5-7 m from the forest edge (Suchockas 2001). Owing to the comparably higher number of naturally regenerating seedlings of birch, the competition among the seedlings may take place already during the first growth period after seed germination. The number of naturally regenerating birch seedlings was especially large at distance up to 50 m from the forest edge (the number of birch seedlings on average exceeded 70 thousand seedlings per ha, crowns of the seedlings were completely closed with crown cover ranging between 100 % to 250 %) (Table 1, Figures 2 and 3).

At distances of 50 to 100 m from the forest edge, the density of naturally regenerating birch seedlings dropped from 70 to 10 thousand of seedlings per ha. Most probably, the edge of the new birch stand will be at al the distances of 110 m from the forest edge (the seed source). Further from the forest edge, only single groups of birch seedlings were regenerating. Small groups of birch seedlings were found as far as 170 m from the forest edge. However, the number of these groups was too little to form a new stand of appropriate productivity.

Table 1. The meansuration data of naturally regenerating 5-year-old birch plantations at the distance from the forest edge

Distance from the forest edge, m	Height of birch seedlings, m	Number of seedlings /ha	Crown cover %
20	2.25±0.12	77682±1938	202.27±7.72
35	1.97±0.1	78575±924	155.38±8.12
50	1.76±0.11	71437±1040	137.97±5.13
65	1.51±0.11	59244±885	101.42±7.41
80	1.28±0.17	38330±1330	88.11±11.08
95	1.09±0.15	26891±2480	59.04±10.01
110	0.96±0.11	6504±505	47.08±8.82
125	0.88±0.14	1046±297	29.22±8.45
140	0.89±0.24	551±120	16.31±5.35
155	0.91±0.22	124±66	8.44±4.31
170	0.9±0.17	170±37	11.12±5.32

When moving apart from the forest edge, the height of naturally regenerating birch seedlings was decreasing (Fig. 4). The tallest birch seedlings were found at the forest edge, where the number of naturally regenerating seedlings was largest and, therefore, the competition among the seedlings was most severe. Thus, when the density of naturally regenerating birch seedlings was 80 and 5 thousands of seedlings per ha, the height of the seedlings was 2.2 m and 0.9 m, respectively.

Natural regeneration of birch seedlings was not uniform, there was a large number of empty spaces. When moving apart from the forest edge, the area of empty spaces increased. If no soil preparation is used, the limit for successful natural regeneration of birch stands was 110 m from the forest edge. However, to avoid empty spaces and achieve more uniform natural regeneration, soil scarification is needed (Suchockas 2001).

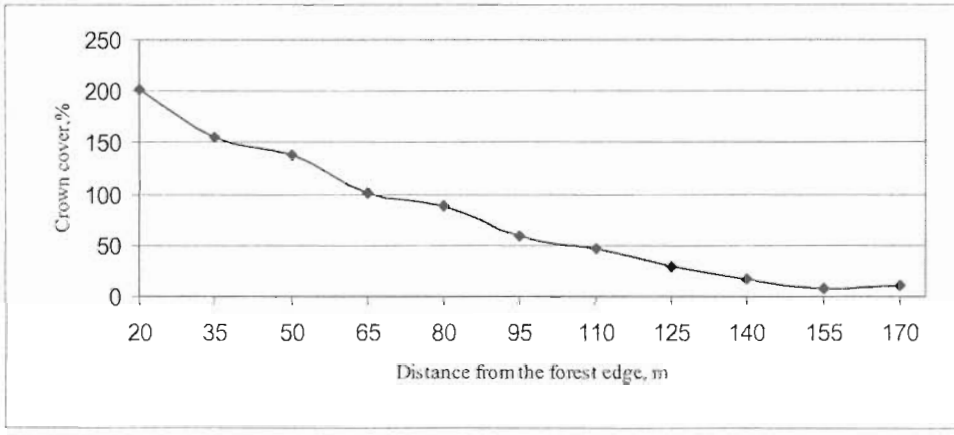

Figure 2. Dependence of the number of naturally regenerating 5-year-old seedlings of birch at the distance from the forest edge

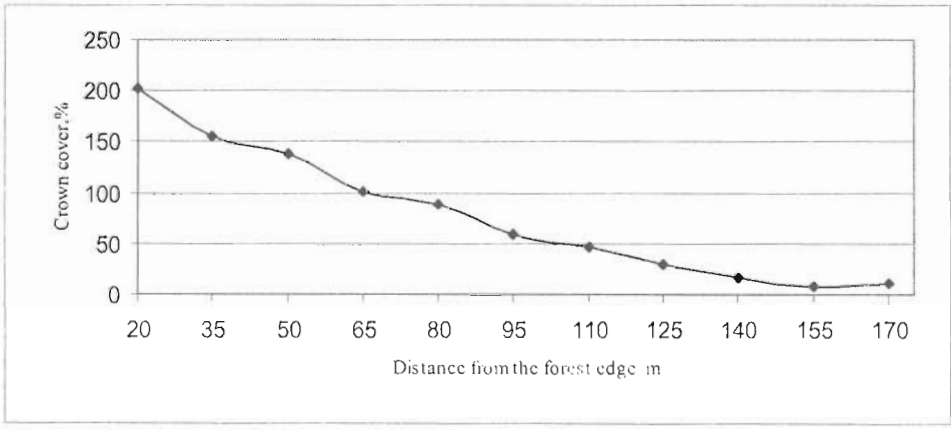

Figure 3. Dependence of the crown cover percentage of the 5-year-old birch seedlings at the distance from the forest edge

Even though, the seeds were spread more or less uniformly over the whole area, regeneration may occur sporadically in patches, because of the variation in germination capacity of seeds on heaps or low-lying spots.

Being comparably small, seed of birch can accumulate only a small amount of nutrients, which is enough for germination only. After germination, roots of the seedling shall reach the mineral soil horizon containing enough moisture and nutrients as soon as

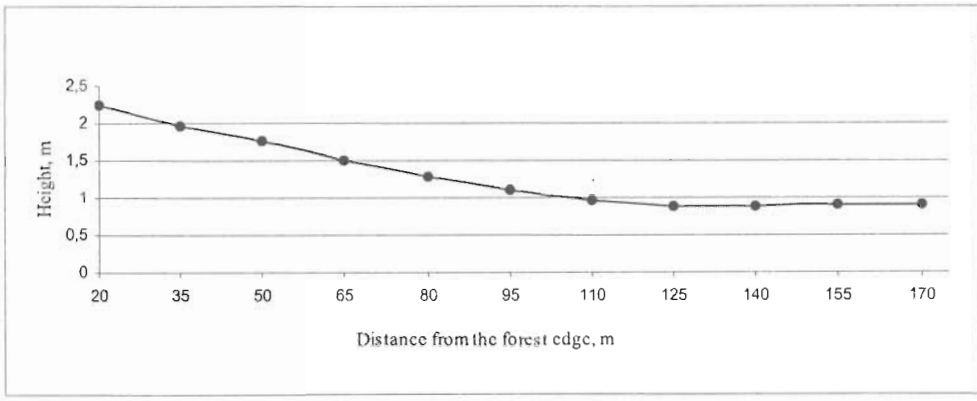

Figure 4. Dependence of height of the 5-year-old birch seedlings at the distance from the forest edge.

possible. The seedlings which promptly after germination failed to reach the mineral soil horizon very soon died. Therefore, on the sites with a heavy sod grass cover, mortality of birch seedlings was very high.

Soil scarification markedly improves the condition for the growth of seedling roots. Therefore, after ploughing the site in furrows, a productive birch stand may regenerate naturally over a much longer distance from the forest edge. During the years of abundant seed harvest, birch seeds may be blown by wind over a long distance and a sufficiently large number of seeds may reach up to 170 m from the forest edge. Therefore, the soil may be scarified and natural regeneration of birch may be expected up to 170 m from the forest edge.

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РАСПРОСТРАНЕНИЕ СЕМЯН И РАЗМЕЩЕНИЕ СЕЯНЦЕВ БЕРЕЗЫ БОРОДОВЧАТОЙ ПРИ ЕСТЕСТВЕННОМ ВОЗОБНОВЛЕНИИ ОПУШЕК ЛЕСА НА БЫВШИХ ПОЧВАХ СЕЛЬСКОХОЗЯЙСТВЕННОГО НАЗНАЧЕНИЯ

В. Сухоцкас

Резюме

Работа посвящена исследованию расстояний распространения семян берёзы на бывших почвах сельскохозяйственного назначения, а также установлению взаимосвязей между расстоянием до источника семян и структурой древостоя. Для этой цели закладывались площадки учёта на естественного облесённых березой опушках леса.

Распространение семян березы начинается в середине июля и продолжается более двух месяцев. Самое большое количество семян (от 2500 до 4000 семян/м^2) выпадает непосредственно у опушки леса, на расстоянии приблизительно равной высоте древостоя. С увеличением расстояния от материнского древостоя количество выпавших семян уменьшается не равномерно.

Самое большое количество сеянцев березы появляется на расстоянии 5-7 метров от материнского древостоя. На расстоянии до 50 м густота молодняка превышает 70 тыс. шт на 1 га, проекционное покрытие крон составляет между 100% и 250%.

Граница нового древостоя кончается на расстоянии 110 метров, однако отдельные группы сеянцев наблюдаются и на расстоянии до 170 метров. Однако в этих группах количество сеянцев недостаточно для формирования продуктивного древостоя. Размещение сеянцев на опушке леса очень неравномерное. Часто встречаются пустые места, распределение которых на площади мало зависит от расстояния от материнского древостоя. Пустые места встречаются и в непосредственной близости к материнскому древостою, не смотря на то, что в этих местах выпадает наибольшее количество семян. Чтобы получить более равномерное размещение сеянцев на площади, перед выпадом семян необходима подготовка почвы.

Ключевые слова: береза, естественное облесение, сеянцы, семена.