Electronic Journal of Polish Agricultural Universities is the very first Polish scientific journal published exclusively on the Internet, founded on January 1, 1998 by the following agricultural universities and higher schools of agriculture: University of Technology and Agriculture of Bydgoszcz, Agricultural University of Cracow, Agricultural University of Lublin, Agricultural University of Poznan, Higher School of Agriculture and Teacher Training Siedlce, Agricultural University of Szczecin, and Agricultural University of Wroclaw.

ELECTRONIC JOURNAL OF POLISH AGRICULTURAL UNIVERSITIES

2001
Volume 4
Issue 2
Series FORESTRY

BARSZCZ A., KARPIERZ M. 2001. THE INFLUENCE OF FOREST DENSITY INDEX AND ALTITUDE ON SELECTED FEATURES OF THE BILBERRY (*VACCINIUM MYRTILLUS* L.) BASE IN MOUNTAIN STANDS **Electronic Journal of Polish Agricultural Universities**, Forestry, Volume 4, Issue 2.
Available Online http://www.ejpau.media.pl

THE INFLUENCE OF FOREST DENSITY INDEX AND ALTITUDE ON SELECTED FEATURES OF THE BILBERRY (*VACCINIUM MYRTILLUS* L.) BASE IN MOUNTAIN STANDS

Anna Barszcz, Mariusz Karpierz
Department of Forest and Wood Utilization, Agricultural University of Cracow, Poland

ABSTRACT

The research was conducted in the lower forest zone, in Stary Sącz Forest District. It concerned the variability of features of the bilberry base in groups of stands which differed as to their forest density index and altitude. The research proved a modifying influence of the growth conditions of bilberry on its fructification, features of fruit and the height of dwarf shrubs. It confirmed statistically the significance of differences in the intensity of fructification, weight and diameter of berries depending on forest density index (including open areas). Altitude had a significant effect only on fructification.

Key words: bilberry, site, altitude, fructification, features of fruit, height of dwarf shrubs

INTRODUCTION AND AIM

Forest environment, formed by e.g. site fertility, access to light and climatic features, modifies the flora of the forest floor which develops under the canopy of a forest stand. One of the undergrowth species common in Poland is bilberry. This species favours coniferous forest sites but it can occur in deciduous forests if the stands are thinned and soils acidified. Bilberry grows well in semishade, and even under the canopy of dense stands, although it does not bear fruit then [5]. In the far north of Europe or high in the mountains, bilberry occurs only in open areas. Research showed that fructification and features of berries are greatly influenced by human activity, e.g. industrial air pollution and mineral fertilizers [2,6].

In the estimation of yield per 1 ha of the raw material bases of fruit-bearing species, the knowledge of reactions between internal factors, described during taxation work, and the dynamics of fructification and expansion over an area is of key significance. It allows for forecasting and planning of the harvesting of the fruit which has industrial significance.

This research is an attempt to determine the influence of selected external factors: forest density index and altitude on the intensity of fructification, features of fruit and the height of dwarf shrubs of bilberry.

METHODS

The research was conducted in the vegetation season of the year 2000, in the lower forest zone, in Stary Sącz Forest District (Regional Directorate of State Forests Kraków), in the Forestry Gaboń and Forestry Obidza, where bilberry occurs in great quantities [7]. Twenty-four forest stands were selected at random, taking into consideration two ranges of forest density index ($1^{st} \leq 0.6$ and $2^{nd} > 0.6$) and two ranges of altitude (1^{st} below 1000m and 2^{nd} above 1000m above sea level). Each variant of the experiment, due to the combination of forest density index and altitude, was represented by 6 forest stands. Additionally, the research was conducted in 12 open areas where bilberry occurred, six of which were located below and six above 1000 m above sea level.

Fructification was analysed by means of determination of the weight of berries collected from sample plots of 1 m^2 each, located in places representative of the conditions present in stands or in open areas. Altogether thirty-six plots were set up. The average weight of a single berry and its average diameter were determined as an arithmetic mean value of 100 berries in each sample plot. Moreover, in each stand and open area, the height of dwarf shrubs was measured, selecting at random 3 neighbouring items in 6 places. Altogether the height of 648 shrubs was measured. The classification of Głowacki was used in this research [3].

The analysis of field data for each of the selected features and the consideration of the variants (resulting from the combination of forest density index and altitude) allowed for the calculation of mean values and variability coefficients. Next, the character of the data distribution was examined using Kołmogorow-Smirnow test, at the significance level $p = 0.05$. This formed the basis for an analysis of the significance of differences between the mean values of both groups of data which characterized the bilberry base depending on altitude. The significance of differences between the mean values of features of bilberry depending on forest density index (3 groups of data) was examined using the variance analysis [1].

RESULTS OF RESEARCH AND THEIR ANALYSIS

The fructification of bilberry in the examined area ranged between 40.10 g/m^2 on average in the densest stands (with forest density index over 0.6) and 63.03 g/m^2, i.e. by about 57% more, in open areas (Fig. 1). The intensity of fructification at the altitudes above 1000 m was by about 67% greater than at lower altitudes (Fig. 2).

Figure 1. Intensity of fructification of bilberry depending on forest density index

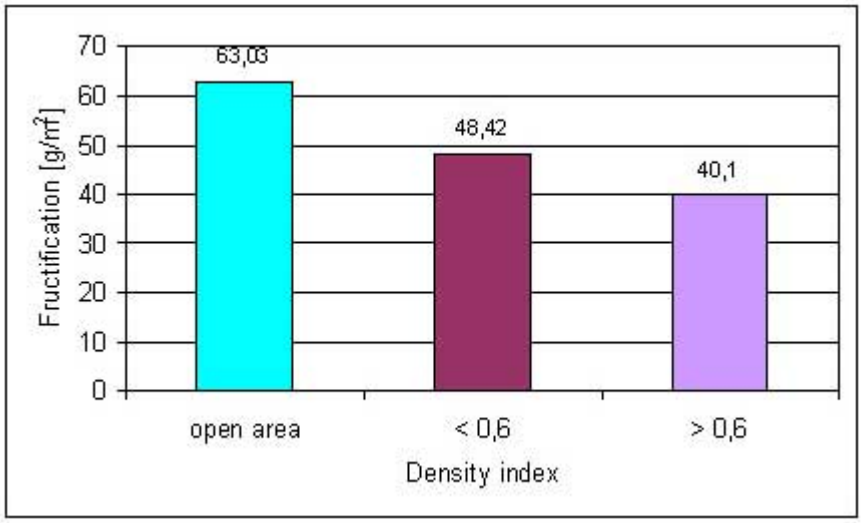
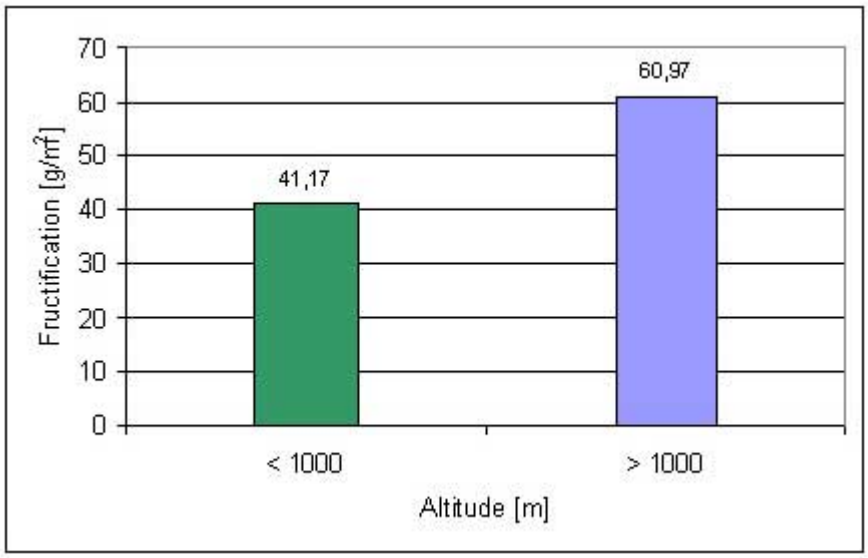


Figure 2. Intensity of fructification of bilberry depending on altitude



The same feature considered against the background of the combined forest density index and altitude had a wide range: from 31.13 g/m^2 on average at the altitude below 1000m, with forest density index exceeding 0.6, to 75.47 g/m^2, i.e. by 142% more, in open areas located above 1000 m above sea level. Fructification was the most variable in stands situated at the altitudes below 1000m, with their forest density index smaller than or equal to 0.6 (variability coefficient about 37%). When forest density index was the same but areas were at higher altitudes, fructification has the smallest variability: about 15% (Table 1).

Table 1. Characteristics of fructification of bilberry depending on forest density index and altitude

Density index and altitude	Average value [g/m^2]	Minimum value [g/m^2]	Maximum value [g/m^2]	Coefficient of variability [%]
Open area ≤ 1000	50.59	30.64	69.48	29.67
Open area > 1000	75.47	56.91	107.18	24.57
≤ 0.6 ≤ 1000	41.70	19.00	55.27	37.44
≤ 0.6 > 1000	57.84	47.57	71.47	15.26
> 0.6 ≤ 1000	31.13	17.01	44.62	31.89
> 0.6 > 1000	49.07	34.52	60.18	22.27

Weight of single berries ranged between 0.26 g on average in open areas and 0.33 g, i.e. by about 27% more, in stands where forest density index exceeded 0.6 (Fig. 3). This feature was only slightly differentiated if altitude was taken into consideration, and its value was only a little smaller at the altitude above 1000 m in comparison with areas located lower (Fig. 4).

Figure 3. Weight of single berries depending on forest density index

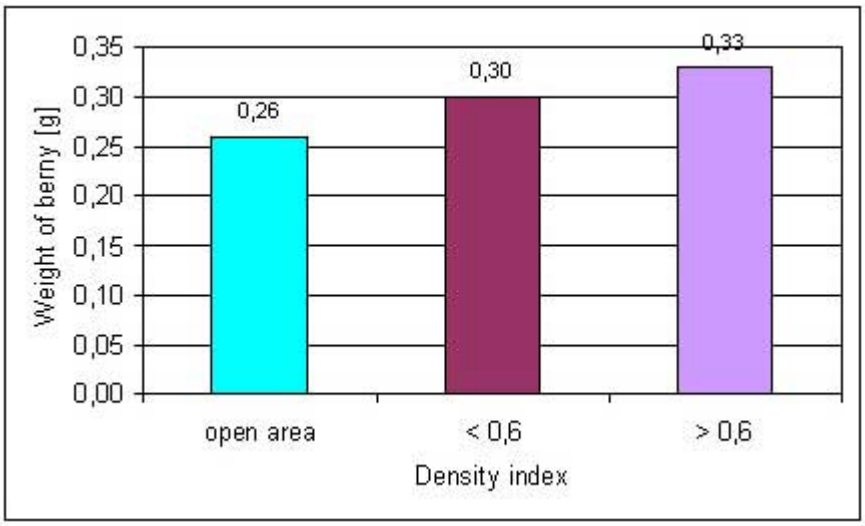
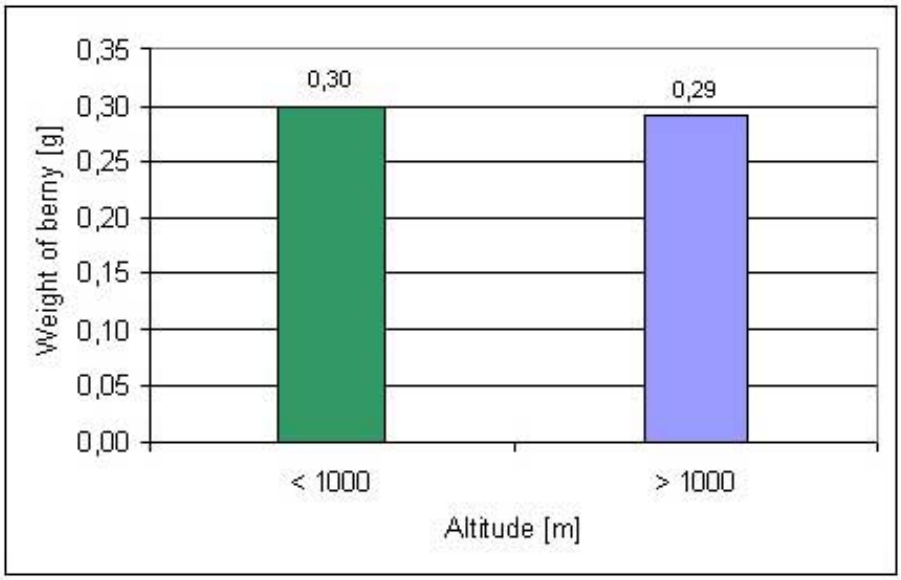


Figure 4. Weight of single berries depending on altitude



With the combined influence of forest density index and altitude, the average weight of a single berry ranged from 0.24 g in open areas at the altitude below 1000 m to 0.33 g in all areas under research where forest density index exceeded 0.6, independent of their location (this feature was the least variable here) (Table 2).

Table 2. Characteristics of weight of single berries depending on forest density index and altitude

Density index and altitude	Average value [g]	Minimum value [g]	Maximum value [g]	Coefficient of variability [%]
Open area ≤ 1000	0.24	0.19	0.29	16.09
Open area > 1000	0.28	0.19	0.35	19.76
≤ 0.6 ≤ 1000	0.32	0.27	0.37	11.36
≤ 0.6 > 1000	0.28	0.23	0.34	15.13
> 0.6 ≤ 1000	0.33	0.30	0.39	9.96
> 0.6 > 1000	0.33	0.28	0.37	10.77

Similarly to weight, also berry diameter had its range of values relatively small. The smallest berries, with the average diameter of 0.73 cm, were collected in open areas. Fruit was a little bigger if the access to light was smaller. In the stands whose forest density index exceeded 0.6, the average diameter was 0.77 cm, being by about 5% bigger than the one found in open areas (Fig. 5). An analysis of the size of berries depending on location gave an almost identical result in both groups of stands (Fig. 6).

Figure 5. Diameter of berries depending on forest density index

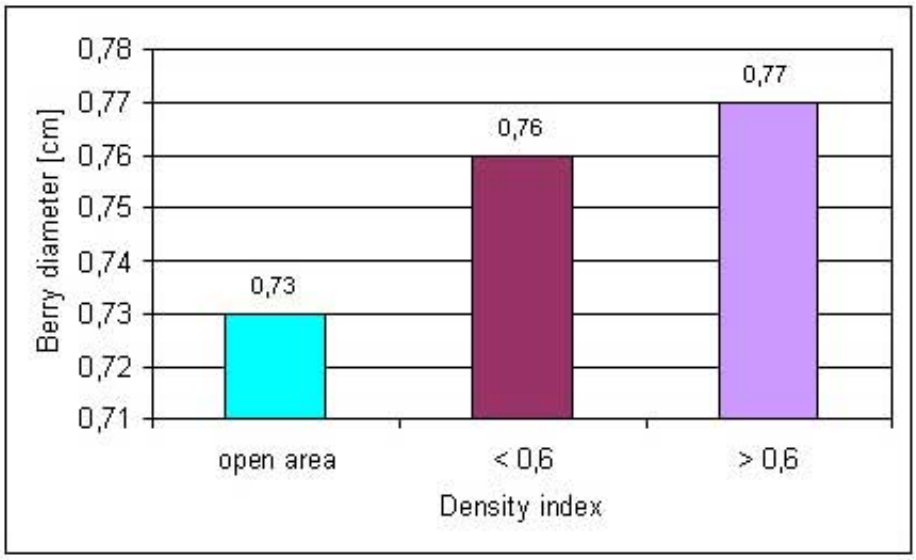
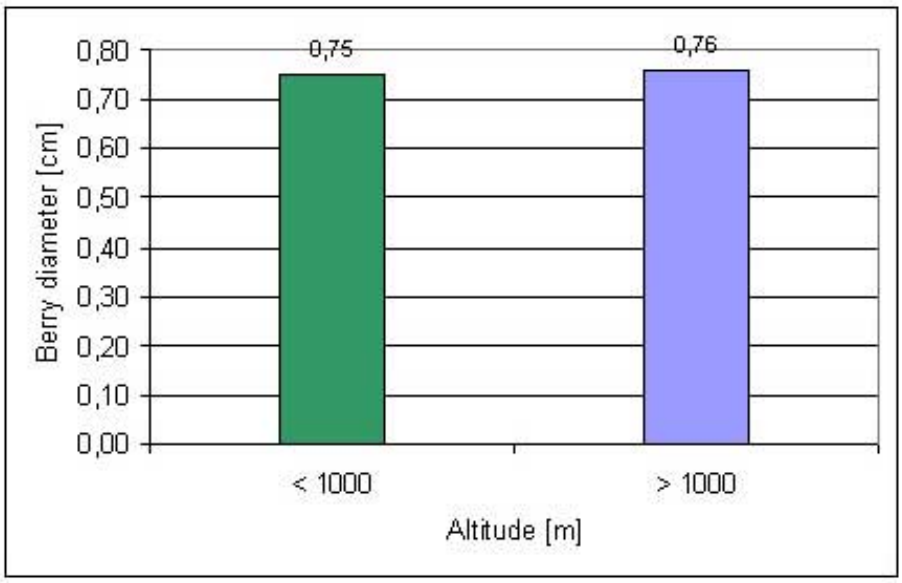


Figure 6. Diameter of berries depending on altitude



An analysis of the joint influence of forest density index and altitude showed that the fruit with the smallest diameter occurred in open areas at the altitude of over 1000 m above sea level. The biggest fruit (diameters by about 11% bigger than the minimum) was collected from dwarf shrubs growing in the stands with the density over 0.6, located over 1000 m above sea level. Variability coefficients of this feature are small, in most cases not exceeding 10% (Table 3).

Table 3. Characteristics of diameter of berries depending on forest density index and altitude

Density index and altitude	Average value [cm]	Minimum value [cm]	Maximum value [cm]	Coefficient of variability [%]
Open area ≤ 1000	0.70	0.65	0.79	5.74

Open area > 1000	0.75	0.69	0.84	5.52
≤ 0.6 ≤ 1000	0.76	0.68	0.89	6.71
≤ 0.6 > 1000	0.74	0.68	0.78	4.96
> 0.6 ≤ 1000	0.77	0.69	0.84	6.36
> 0.6 > 1000	0.78	0.50	0.91	10.13

In open areas bilberry formed the biggest dwarf shrubs. According to the classification of Głowacki [3], they are in class 3, i.e. high. With smaller access to light, shrubs were lower. In stands with forest density index over 0.6, bilberry was, on average, by 20% lower than in open areas (Fig. 7). These shrubs were included in class 2, i.e. average. Dwarf shrubs in areas below 1000 m above sea level were in the average class; they were by about 17% lower than the ones growing at higher altitudes (Fig. 8).

Figure 7. Height of dwarf shrubs depending on forest density index

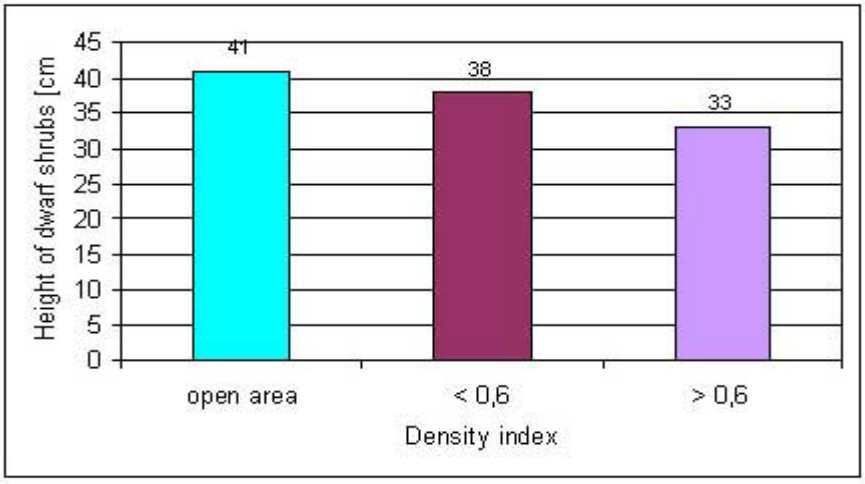
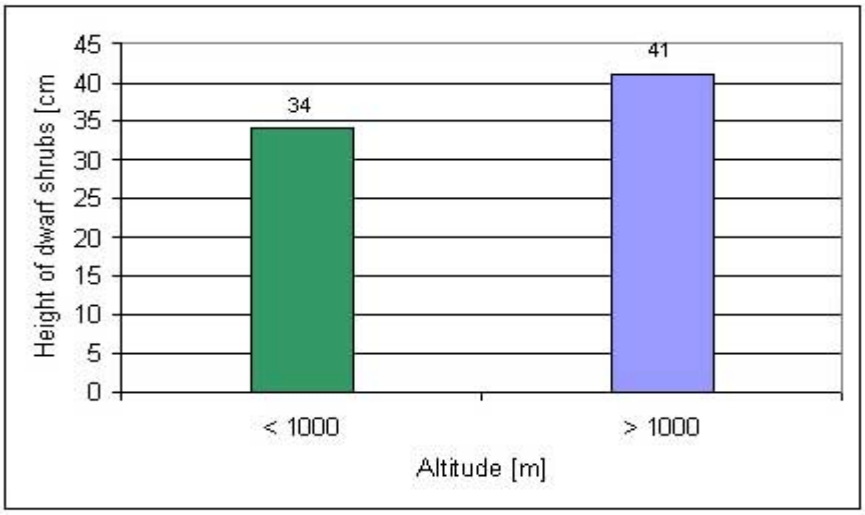


Figure 8. Height of dwarf shrubs depending on altitude



Considering the joint factors, the smallest height of shrubs was noted in areas with forest density index over 0.6 and altitude below 1000 m above sea level; the largest height (i.e. by about 58% larger) – in open areas located at altitudes over 1000 m above sea level (Table 4). The height of shrubs, like the diameter of berries, was very stable. The variability coefficients of this feature slightly exceeded 10% only in two variants (Table 4).

Table 4. Characteristics of height of dwarf shrubs depending on forest density index and altitude

Density index and altitude	Average value [cm]	Minimum value [cm]	Maximum value [cm]	Coefficient of variability [%]
Open area ≤ 1000	33	31	35	4.05
Open area > 1000	49	41	55	10.46
≤ 0.6 ≤ 1000	38	33	48	10.52
≤ 0.6 > 1000	39	34	44	7.27
> 0.6 ≤ 1000	31	27	35	8.49
> 0.6 > 1000	35	31	41	6.60

Kołmogorow-Smirnow test [1] confirmed on the level p=0.05 that three out of the analysed features of the bilberry base, i.e. fructification, weight and diameter of berries, were characterized by the normal distribution (the negative result was achieved in the analysis of the height of shrubs). The results of the test allowed for an analysis of the significance of differences between average values of these features, grouped according to altitude (the t-Student test) and according to forest density index (the variance analysis).

Using the t-Student test, the hypothesis was accepted assuming that the compared values of features in both groups of data, distinguished according to altitude, were equal. When analysing he fructification, this hypothesis was rejected with the probability p=0.001 in favour of the alternative hypothesis. Thus, in the analysed area, within the lower forest zone, altitude turned out to be the factor which differentiated the amount of fructification in a significant way. The zero hypothesis, which assumed lack of the influence of location, was confirmed in the analysis of weight and diameter of berries (Table 5).

Table 5. Examination of significance of differences of features of bilberry base by means of t-Student test

Analysed feature	Probability	Result of research
Fructification	0.000	+
Weight of single berry	0.683	-
Berry diameter	0.228	-

+ the average values of the compared features differ significantly
- lack of significant differences between the average values of the compared features

Using the variance analysis, the degree of differentiation of features of bilberry was examined in relation with forest density index (including open areas). The result confirming the significance of differences was received for the amount of fructification as well as weight and diameter of berries (Table 6).

Table 6. Examination of significance of differences of features of bilberry base by means of the variance analysis

Analysed feature	F	p	Result of research
Fructification	5.7432	0.007	+
Weight of single berry	7.2813	0.002	+
Berry diameter	6.5996	0.002	+

F – value of function
+ the average values of the compared features differ significantly

The research on the bilberry base which was the closest to this analysis due to its scope and methods was carried out by Małecki in lowland areas [4]. The author did not consider altitude, instead taking into account the differentiation of the base depending on the site type of forest. The distinction of the two groups of data on the basis of altitude can also be applied to forest sites in Stary Sącz Forest District. This is because, except one sample plot, all forest stands situated above 1000 m above sea level were found in the mountain mixed coniferous forest and stands situated at lower altitudes - in mountain mixed broadleaved forest [7]. In the light of such a division, a comparison of the analysis of the mountain and lowland bilberry bases allows for a conclusion that in both regions only fructification was significantly influenced by a site type of forest. Moreover, significant differences in the weight and diameter of berries growing in different site conditions were proved in lowlands. The factor which differentiated the mountain base more significantly than the lowland one was forest density index. While in lowlands forest density index only influenced the intensity of fructification [4], in the mountains it also had an effect on diameter and weight of berries.

SUMMING UP AND CONCLUSIONS

1. The results of research conducted in the lower forest zone in Stary Sącz Forest District proved the differentiation of the features of the bilberry base depending on forest density index (including open areas) as well as on altitude.
2. The most intensive fructification and the highest dwarf shrubs in the vegetation season of the year 2000 were noted in open areas located above 1000 m above sea level. The weakest fructification and the lowest shrubs were in the stands located below 1000 m and where forest density index exceeded 0.6.
3. Within the base under research, the heaviest fruit grew in stands with density over 0.6 in both altitude zones. Moreover, in sample plots with density over 0.6, located above 1000 m, fruit was also the largest. The lightest and smallest fruit was noted in open areas situated below 1000 m above sea level.
4. An analysis of the significance of differences between the average values of the features of the examined base stated:
    a. statistically significant differences in fructification, weight and diameter of berries depending on forest density index,
    b. statistically significant differences in fructification depending on altitude,

c. lack of significant differences in weight and diameter of berries depending on altitude.

5. Forest density index, which in practice refers to the amount of light reaching the forest floor and to the competition of plants as to their access to nutritious elements in the soil, influenced the features of the bilberry base more considerably than altitude. A comparative analysis showed, moreover, that in the mountains forest density index is a more significant element affecting the yield of bilberry than in lowlands.

REFERENCES

1. Bobrowski D. 1980. Probability mathematics in technical applications. WNT, Warszawa.
2. Cybulko T. 1965. Research on mineral fertilizing of bilberry (*Vaccinium myrtillus* L.) growing in the natural conditions. Rocz. WSR Pozn., 27, 45-54
3. Głowacki S. 1968. Classification of bilberry formations. Zesz. Nauk. SGGW w Warszawie, 10, 103-107.
4. Małecki T. 2000. The bilberry (*Vaccinium myrtillus* L.) base within Krzeszowice Forest District. KULiD, AR Kraków (typescript).
5. Nowiński M. 1956. Medicinal plants in the Polish flora. PTPN, Nauki Biol., 4, Poznań.
6. Muszyński Z., Muszyński J. 1997. The influence of industrial pollution on non wood forest products. Post. Tech. L., 63, 11-17.
7. Forest management plan. 1996-2005. Stary Sącz Forest District.

Submited:

Anna Barszcz, Mariusz Karpierz
Department of Forest and Wood Utilization
Agricultural University of Cracow
31-425 Kraków, Al. 29 Listopada 46, Poland
e-mail: rlbarszc@cyf-kr.edu.pl