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BIOINDICATION ABILITY OF TREE AND SHRUB SPECIES UNDER INDUSTRIAL ENVIRONMENTAL POLLUTION

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SYNOPSIS

A morphological study of five tree and shrub species under different type of industrial pollution by three parameters (growth of the annual twigs, number of leaves on the annual twigs and area of leaves) has been made. There has been proved that the species can be used as pollution bioindicators in the studied regions. All of the species could be used as indicators for pollution presence only. The three morphological parameters are bioindicators but the area of leaves is the most significant index for all of the studied species. The “growth of the annual twigs” is defined for *Robinia pseudoacacia* L., *Carpinus orientalis* Mill., *Quercus pubescens* Willd. and *Quercus cerris* L. The third parameter “number of leaves on the annual twigs” is appeared as a bioindicator for *Crataegus monogyna* Jacq., *Carpinus orientalis* Mill. and *Quercus pubescens* Willd.

INTRODUCTION

The disturbed ecological balance in industrial polluted areas becomes of a global problem. Bioindication has determining place in the system of environmental monitoring. The use of plants as biomonitors or accumulators of the environment polluting substances is the most successfully in economical and ecological aspects (MANNING, FEDER 1980, KOVÁCS 1992). The plants’ reactions to atmospheric pollution allow (POSTHUMUS 1988, SIKORA, CHAPPELKA 2004) to set up the early presence of pollutants and their identification in the air on the base of plant species affected, to determine the total effect of all environmental factors including air pollution, as well as to use plants as a sensitive system for early diagnostics of environment state. Because of a range of advantages: integration of the pollutants biological effect, easy following and obtaining of results, plant bioindication is outlined as a valuable source for characterization or following of air quality (GARRECC 1999).

The most often used practical methods for biomonitoring of air polluted regions include the morphological changes in higher plants (SCHUBERT 1988, TINGEY 1989). That is due to the fact the morphological investigations are in conformity with the main requirements for bioindication (SCHUBERT 1988): relatively fast implementation, rather exact and reproductive results, using of more quantity of objects, possibility to carry out them in the experimental plots, without use of special laboratories. The most suitable objects for air pollution bioindication are the trees and shrubs. They are characterized with relatively long life and big accumulation ability to polluting substances. Gas-resistance of plants, as a specific species property, can be used for the aims in bioindication of air pollution.

The aim of the study was by statistical multifactorial analysis of the data from comparative investigation of five tree and shrub species under industrial pollution to assess the value changes in morphological parameters and possibility for usage the species as pollution bioindicators.

MATERIAL AND METHODS

Objects of research were five tree and shrub species, as follows: *Robinia pseudoacacia* L.(Black Locust), *Quercus cerris* L. (Turkey Oak), *Quercus pubescens* Willd. (Downy Oak, Pubescent Oak), *Carpinus orientalis* Mill. (Oriental Hornbeam) and *Crataegus monogyna* Jacq. (Common Hawthorn). The studied species, according to the researches and suggested range of tolerance and sensitivity by the majority of authors have approximately equal - high degree of resistance at pollution with SO_2, NO_x, NH_3, HF and organic compounds. *Quercus pubescens* also *Carpinus orientalis* because of their quite limited distribution in southern Europe, southwest Asia, Crimea and Caucasus, data for their resistance are lacking, but for Bulgaria the species are defined as resistant under industrial pollution (PROKOPIEV 1978, GATEVA et al. 1987). All of the species are resistant to the conditions of the industrial pollution in Devnya (ZELYAZKOV et al. 1986). Some of the studied species (*Robinia* pseudoacacia, *Crataegus monogyna*) are recommended for planting in I and II zones as well as on the whole territory of the industrial works, except maximal polluting areas (GAEVAYA 1962, KONDRATJUK 1980, KURTEVA 1982), especially around Thermo-Electric Rower Station (*Robinia pseudoacacia*) (KOEV et al 2001), for sanitary-safety belts (*Robinia pseudoacacia*, *Quercus cerris*) (GATEVA et al. 1987) and afforestation of industrial embanks (*Robinia pseudoacacia,*) (DELKOV 1988) as well as for green zones in towns (*Robinia pseudoacacia, Quercus cerris*)(DÄSSLER 1981, GATEVA et al. 1987).

From the prominent sources of industrial pollution in Bulgaria the main object for all of species studied was the Devnya industrial region, Varna district by Agropolychim Joint-Stack Company – Devnya. The data from this region are compared with the ones for the following polluters in Bulgaria: Copper smelter in Pirdop town (UMPM – Pirdop), the region of the building Burgas Combined Metallurgical Works, near v. Debelt, Thermo Electric Power Station (TEPS) - "Iskar" Railway Station, Sofia and around the Lead-zink Works in Kurdzhali (Fig. 1). The species studied, except *Robinia pseudoacacia,* are dominants or subdominants of the forest vegetation in the lower woody belt from the regions of Devnya, Burgas Combined Metallurgical Works, near v. Debelt and Lead-zink Works in Kurdzhali town. The Black locust is represented as more compact plantations around UMPM-Pirdop and Devnya industrial region, but with quite limited participation on the territory of TEPS, Sofia. According to data of HEI (Hygienic epidemiological inspection) and the National Automatic System for Ecological Monitoring (Newsletters for environment status of SCSESD* (Scientific Center of State of Environment and Sustainable Development) at MEW (Ministry of Environment and Waters, Bulgaria) the type of pollution and the main pollutants in the investigated regions are represented in Table 1. The study of the Devnya industrial region was carried out in point Drenaka, at 3.5-4.0 km in front of the chemical Works, and as control variant was used the vegetation in point Janavara, that situated at a distance of 20.0 km away from the Devnya region.

Fig. 1. Map of Bulgaria with the studied regions.

The species from UMPM-Pirdop region have been studied around the Works (0.1-1.0 km), as well as in more remote regions - v. Chelopech (6.25 km), locality Kaliman, by v. Anton (10 km) and near threshold Galabetz. As control variants in that region have been used Kaliman, Galabetz, as well as the vegetation from the park of the Institute of Forestry, Sofia, which is far away from industrial and urban pollution in Sofia.

The Railway Station "Iskar" is an industrial area of Sofia, with a great number of works and workshops which gives a mixed type of pollution in the region. The studied species from the TEPS is distributed nearest from the chimney - stack (0.05 km). As a control is used the vegetation from the park of the Institute of Forestry, Sofia, which is far away from industrial and urban pollution.

The study in the region around the Lead-zinc Works – Kurdzhali included two points: I at of 1.00 km from the Works-polluter, and II – Jinzifovo, at 9.00 km far away from the source of pollution and used as a control variant.

The investigation in the region of the building Burgas Combined Metallurgical Works aiming prognosis of the state and development of the lands at a future industrial pollution. The investigated tree and shrub species are dominants of native Quercus coenoses. In the last 2 years of study with the start of activity of the first industrial object, began the primary influence of air pollution on the studied species. As a control from that region is used the most remote point near the v. Zagortci.

The morphological analysis has included the determination of the following three parameters: linear growth of the annual twigs (cm), the number of leaves that have developed on them and the area of leaves (cm^2). The selected indexes reflect the changes in the growth, as far as its total decrease at the tree species in the conditions of industrial environmental pollution has appeared through decrease of the radial growth, the growth in terms of height, the linear growth of the annual twigs, the size and quantity of the needles or leaves (KELLER 1979, MANNING, FEDER 1980). In comparison to the determination of the dry substance of the whole plant, the sensitiveness of indication by measuring of separate organs or the annual twigs growth is much higher (GLUCH 1980). That's why also the changes in the growth, even that in its bigger part non specific, are more sensitive indicators than necroses (GLUCH 1980, JÄGER 1980) and have been implemented widely for status diagnosing of the tree species (LUCHKOV 1980) and at research of their adaptation to industrial pollution (DOROGAN, DJUKOV 1990, KORSHIKOV, TARABRIN 1990). According to MANNING, FEDER (1980), HALBWACHS (1988) and the researches of different authors (NINOVA et al. 1986, VOLKOVA, BELYAEVA 1990, GIRS, ZUBAREVA 1992, GRYSHKO 2002), as well as in conformity with own researches (KURTEVA 1999, KURTEVA et al. 2004), those morphological parameters can be used for fast and premature indication of the effects from the pollution on the growth and development of the plants and their use for planting in industrial regions The plant growth according to TINGEY (1989) together with the morphological responses could be used as examples of possible plant responses and as bioindicators.

The linear growth of the annual twigs was measured linearly, while the area of leaves was determined after ROZNJATOVSKIY (1954), but with modifications: instead of on photosensitive paper, the imprints of leaves were taken on plotting paper and their area (cm^2) was determined by the weighting method.

The investigation was carried out in 2-4-years (1986-1989), in the period of the highest level of air industrial pollution in Bulgaria. There were selected 10-20 individuals from each of species in the studied points. The morphological measurements, as well as the collection of leaf samples for leaf area determination, were realized in the first half of August, when the linear growth of the annual twigs was completed, the number of leaves on them was final and the leaf blades had reached their ultimate size. The measurements were conducted in 50-fold repetitions.

RESULTS AND DISCUSSION

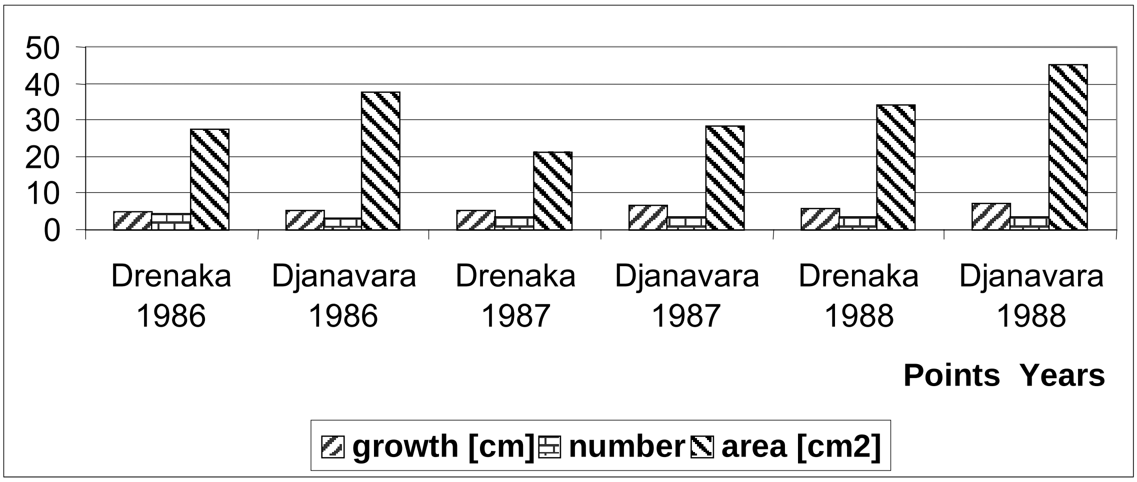
Robinia pseudoacacia was studied in the regions of Devnya, UMPC– Pirdop and TEPS, Sofia in three years period: 1986-1988. There were defined the following points of study: Devnya – Drenaka and Janavara as a control; Pirdop - 0.1, 0.65, 1.0 km, h. Kaliman, and K (control), TEPS – 0.05 km from the chimney – stack and K (control).

Under the chemical pollution in Devnya region with the most variation were the values of the area of leaves, especially in the end of study (1988)(Fig. 2 A). Among the studied parameters the growth of the twigs as well as the leaf area showed values under the controls (point Janavara) for the whole period of investigation (Fig. 2 A). With minimal leaf area (21.36 cm^2) also number of leaves (3.44) on the annual twigs were the specimens of black locust in 1987 (Fig. 2 A). The percent correlation of the values from Devnya as to the control showed decrease of leaf area from 73.1% (1986) to 75.2% for the rest years as well as of twigs' growth in the interval: 79.2% (1987) to 87.4 % (1986) and 82.3% at the end of study (1988). Only in respect of the number of leaves on the twigs the values exceeded the control, particularly in 1986 (138%) and in lower degree at the other years: 103.4% (1988) and 102.7% (1987) (Fig. 2 A). By the development of higher number of leaves compare to the control *Robinia pseudoacacia* partially compensated the lower values of the other parameters. In general, for Devnya region the leaf area and the twigs' growth are outlined as sensitive indexes.

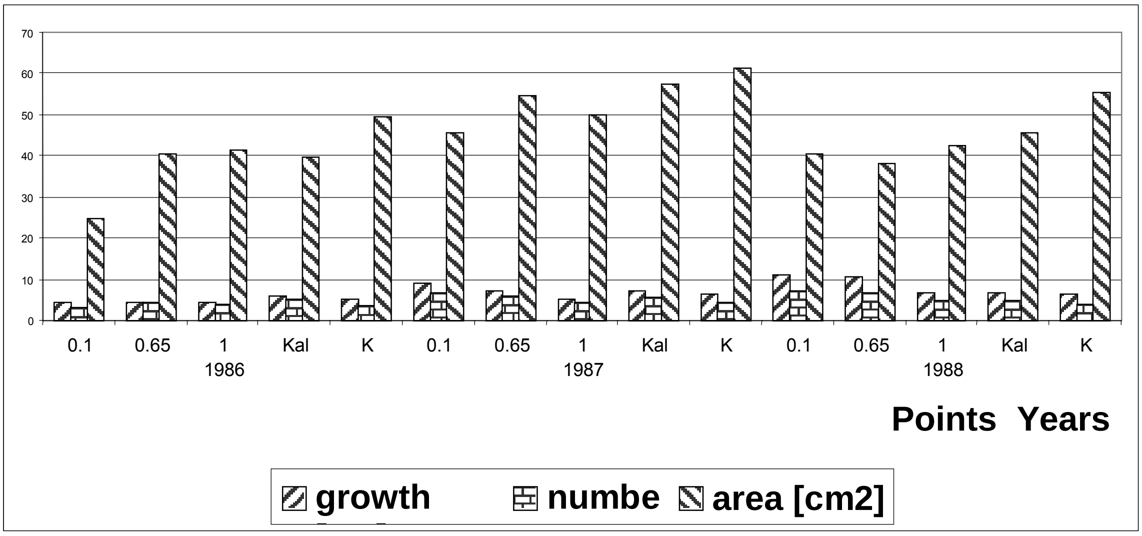
Site	Type of pollution	Main pollutants
1	Agropolychim Joint-Stack Company – Devnya.- chemical Works, with production of fertilizers, PVC, Cement factory, Building constructions Works, TEPS "Devnya" Mixed type of pollution	**dust** (calcium oxide, calcium carbide, coal, cement etc.), soot, **CO_2**, CO, **SO_x, H_2S, HF, NH_3, Cl_2, NO_x**, N_2O, non methane VOCs, CH_4. and from the traffic (road and railway) - dust, SO_2, formaldehyde, **Pb aerosols** and number of heavy metals.
2	Copper smelter in Pirdop town (UMPM – Pirdop),	dust, **SO_2**, H_2S, **aerosols of H_2SO_4, Pb, Cu As** and NO_2.
3	Thermo-Electric Power Station "T. Kostov" - "Iskar" Railway Station, Sofia (TEPS)*	mainly **SO_2**
4	Lead-zink Works in Kardzhali Mixed type of pollutioin	**Pb, Cd, Zn**, Ni, and in lower degree – Cu.
5	Burgas Combined Metallurgical Works, near v. Debelt	in the last two years - SO_2

Table 1 Type of pollution in the studied sites: 1 – Devnya; 2 – Pirdop; 3 – v. Debelt; 4 – Kurdzhali; 5 – TEPS, Sofia
Legend: pollutants in bold are with concentrations, exceeding LPC (Limited permisible concentration).

A


50
40
30
20
10
0
Drenaka 1986
Djanavara 1986
Drenaka 1987
Djanavara 1987
Drenaka 1988
Djanavara 1988
Points Years
growth [cm]
number
area [cm2]

B


70
60
50
40
30
20
10
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0.1
0.65
1
Kal
K
1986
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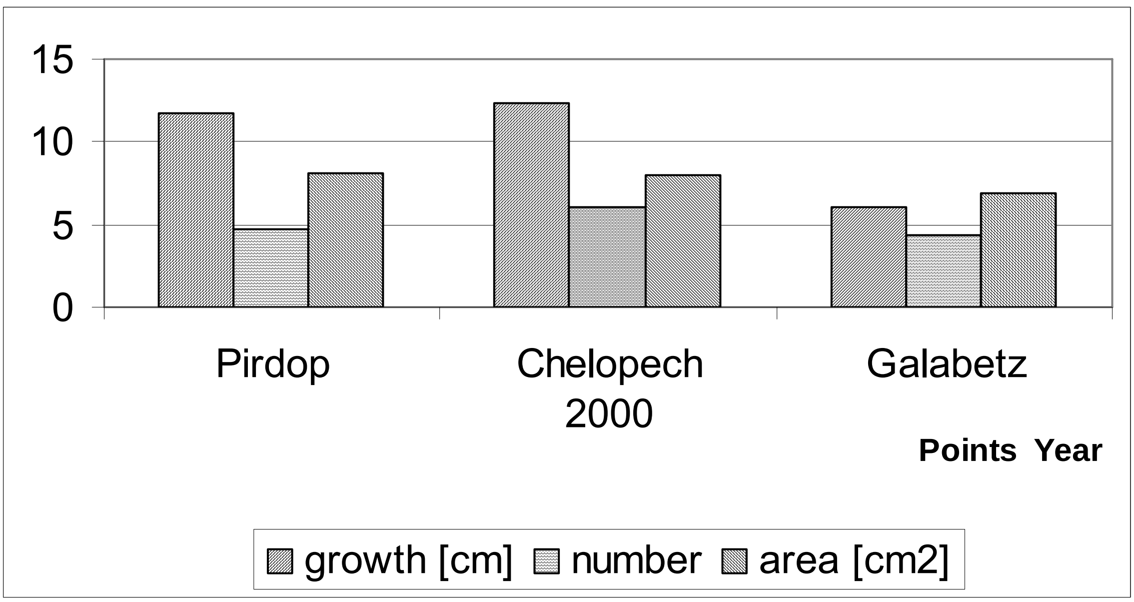
area [cm2]

C


15
10
5
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Pirdop
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Galabetz
Points Year
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area [cm2]

D

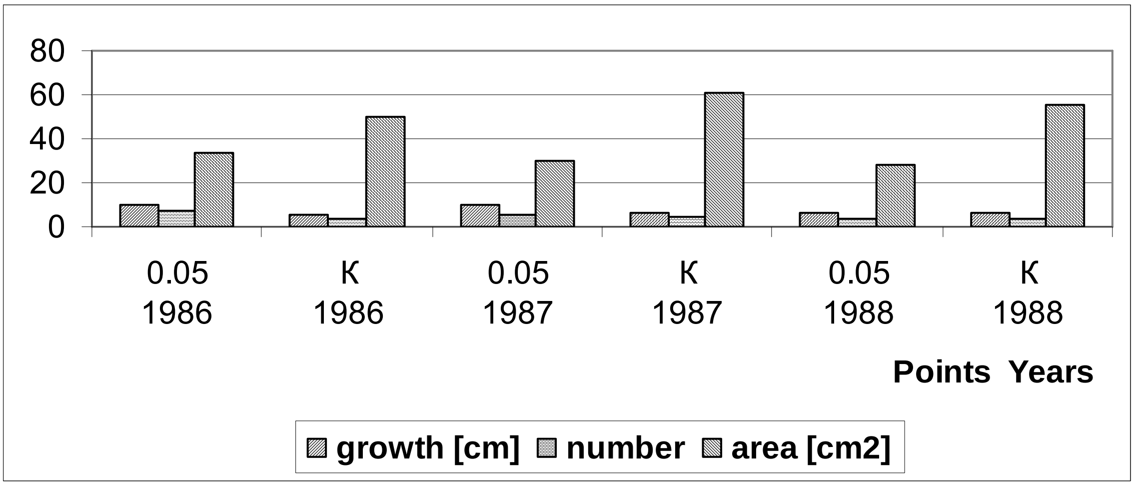


Fig. 2. Average values of the morphological parameters for *Robinia pseudoacacia* L. at industrial environmental pollution. (A) – Devnya region; (B) Around UMPM-Pirdop; (C) Points under the influence of UMPM-Pirdop; (D).- TEPS, Sofia. – Growth of the annual twigs {cm}; .. - Number of leaves on the twigs; - Area of leaves {cm^2}.

In the region of UMPM-Pirdop more significant differences in the values were registered, as for the mentioned above for Devnya, in respect of the leaf area, which in all of the points remained lower the control during the whole period of research (Fig. 2 B). The variation of data for this index is greater in 1986. The most reduction of the area of leaves in comparison with the control was registered closely to the Works (0.1 km) in 1986 – 50% and at a distance 0.65 km in 1988 (68.8%) from K (Fig. 2 B). The number of leaves on the black locust twigs was higher the control in the two last years, especially in the end of study (1988). The growth of the twigs was lower the control (1986) with 89% (0.1 km) and 82% (0.65 km), but in the next years exceeded the control values in these points, especially to the end (1988), accordingly 174.3% and 163% (Fig. 2 B). By the development of higher growth of the annual twigs and better leafing of them, especially for the last two years (1987,1988) the locust partially compensated the strongly limited leaf area. The data of the morphological parameters for the specimens from I. Kaliman showed the bigger growth of the twigs as the greatest number of leaves on them in 1986, correspondingly 117.6% and 138.8%, but the leaf area was most limited too (80.1%) ((Fig. 2 B). The maximal values of the first two parameters in 1987 perhaps compensated the leaf area diminution. All this prove, that this point, nevertheless that situated at a distance of 10.0 km from the pollution source, also is under the influence of the pollution and can not used as a control.

At the studying of the growth and development of *Robinia pseudoacacia* in 3 regions under different degree of pollution from UMPC – Pirdop (Pirdop, Chelopech, Galabets), it was registered the highest growth of the twigs as well as higher values for number and area of leaves in the point Chelopech compare to Galabets (Fig. 2 C).

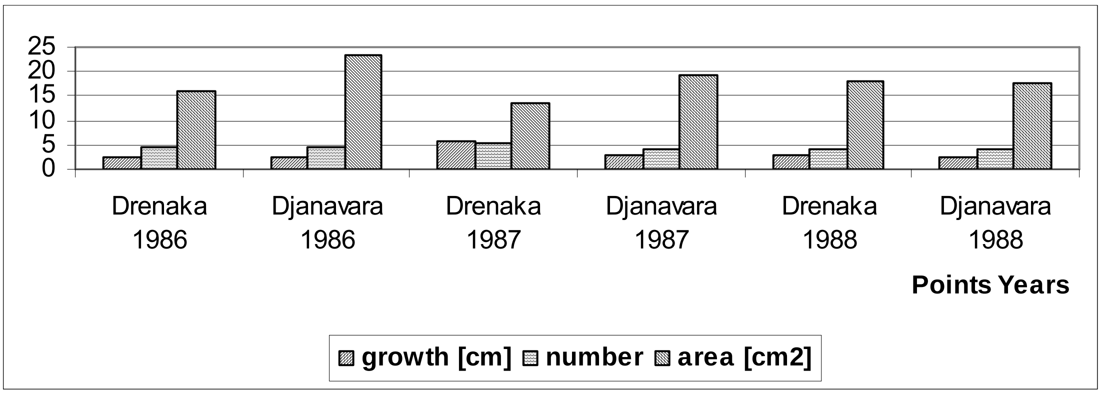
This indirectly proved that the last region, albeit far remote from the polluter, is under the influence of the pollution too.

The data regarding the twigs' growth and number of leaves on them for *Robinia pseudoacacia* closely to the chimney – stack (0.05 km) of TEPS showed unidirectional response - significantly higher growth of the twigs maximally exceeded the control in 1986 (200%) to 169.2% (1987) also the greater number of leaves, accordingly 191% and 112% for the same years (Fig. 2 D). Maximal twigs' growth of the black locust around TEPS in Kiev (Ukraina) was registered by the author (KURTEVA 1982) as well as under pollution from non-ferrous smelter by NINOVA et al. (1984). Increasing of the growth of annual twigs of the species was confirmed according to GRYSHKO (2002). In the end (1988), on the contrary, was registered decreasing in the values of these parameters to the control ones. This fact, in our opinion, is connected mainly with the strong drought. In respect of "area of leaves" the situation is quite the reverse – it was clearly reduced during the whole period of investigation, from 68% to the strongly 2-fold diminution – 50% (1987) and 51% (1988)(Fig. 2 D). This is due to the premature loss of foliage till to heavy defoliation and secondary development of leaves with quite smaller sizes under industrial pollution observed also by KULAGIN (1974), ILKUN (1978), SIKORA, CHAPPELKA (2004) and by the author (KURTEVA 1982) as well as the reduction of the leaf length and the number of the leaflets registered by KOEV et al. (2001) in addition with the drought.

Data from the morphological research of *Robinia pseudoacacia* have shown that the species can be used as indicator only for pollution presence, without specificity. As indicators with predominant significance can be implemented "area of the leaves" and in lower degree -"linear growth of annual twigs". This decreasing range of sensitivity of the morphological parameters confirmed the results from the dispersion analysis of the same species under air pollution in Kiev (KURTEVA, KALCHEV 1984).

The study of *Quercus cerris* in the regions of Devnya and the Burgas Combined Metallurgical Works, around v. Debelt includes three (Devnya) and four (Debelt) years period with the mentioned above points for Devnya region and for Debelt - 8 points, among which the one near v. Zagortci was as a control. The results of the implemented analysis are presented on Fig. 3.

A



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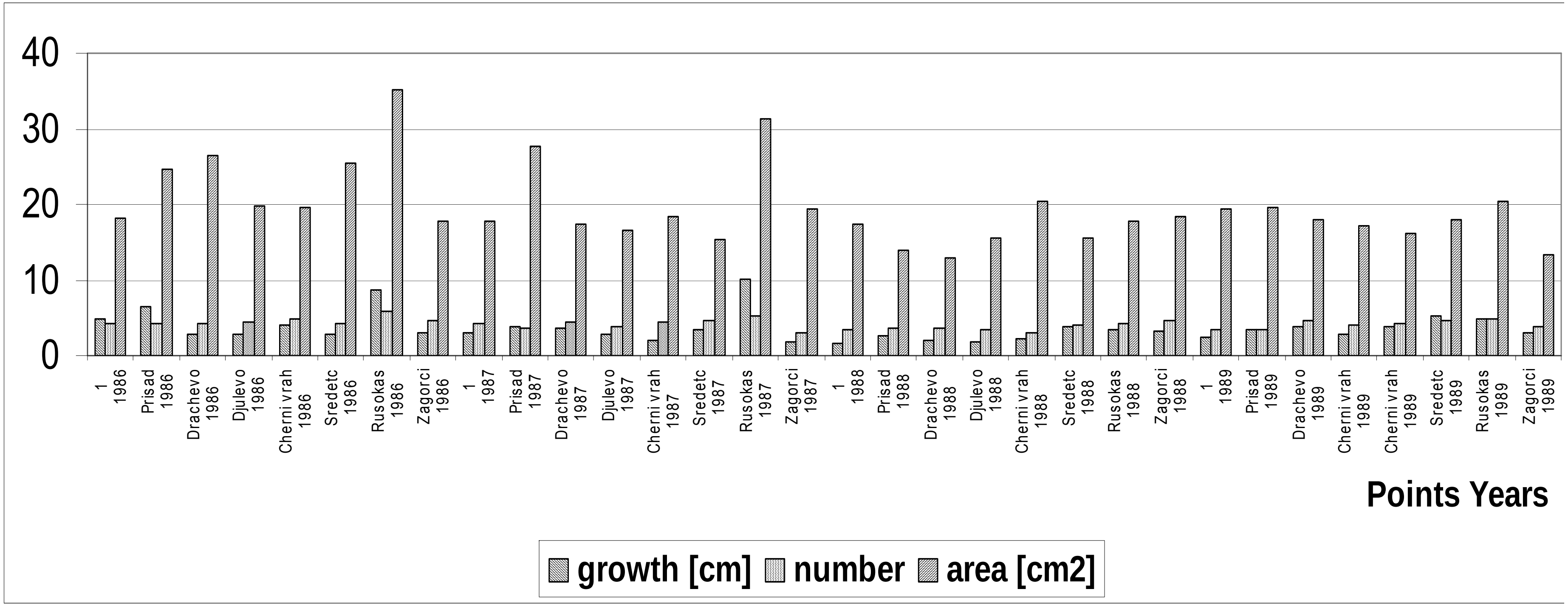


Fig. 3. Average values of the morphological parameters for *Quercus cerris* L.. in industrial environment. (A) – Devnya; (B) –Burgas Works, Debelt….- Growth of the annual twigs {cm}; - Number of leaves; - Area of leaves {cm^2}.

More great differences in values from the polluted and control points in the region of Devnya were registered regarding the growth of the twigs in the last two years as well as the leaf area but in the first two years (Fig. 3 A). In the beginning (1986) the values of the twigs' growth were resembled in two points. Next, under chemical pollution, is shown the growth increasing from 205.7% by the maximal value (5.72 cm) (1987) to diminution (120.8%) in the end of study compare to the control (Fig. 3 A). The area of leaves, on the contrary, was lower the control in the first two years, especially in 1986 (68.3%) and for the second year with slight high increase to 69.4%. To the end of investigation leaf area increased but at least exceeded (102%) the control value (Fig. 3 A). The turkey oak response to the pollution by number of leaves was not unidirectional. So, in 1986 the values from the two points were resembled to the ones for the growth. The maximal number of leaves (5.51) was accounted in 1987 that consisted 138.8% from the control as compensation to their decreased area (Fig. 3 A). The outlined diminution of the twigs' growth and leaf area in the control point (1988), in our opinion could be due to the strong drought in the same year.

In the region around Metallurgical Works, Debelt *Quercus cerris* responded by alterations in the twigs' growth (1988) as well as the area of leaves (1988, 1989). In the first two years (1986, 1987) the values of the twigs' growth from v. Rusokastro are substantially differed from the rest points and exceeded the control, correspondingly 277.4%. and 542.5% (Fig. 3 B). In 1988 with the appearance of pollution by an initial activity of Stan-300 together with the strong drought the values of all parameters gone down (Fig. 3 B). Then was accounted strong decrease of the growth of the twigs in all of the points as the smallest values for the whole period of investigation were registered closely to the Works (1.0 km) -1.59 cm and near v. Djulevo – 1.80 cm (Fig. 3 B). Stunted growth as well as decreasing of the annual twigs' growth in the broad-leaved trees under industrial pollution are reported according to SIKORA, CHAPPELKA (2004) and KOVÁCS (1992). The study shown that in point Zagortci, accepted as a control, the oak specimens had the minimal twigs' growth and the smallest number of leaves (1987) also leaf area (1989). It was proved that the point near v. Rusokastro could be more suitable as a control than Zagortci (Fig. 3 B).

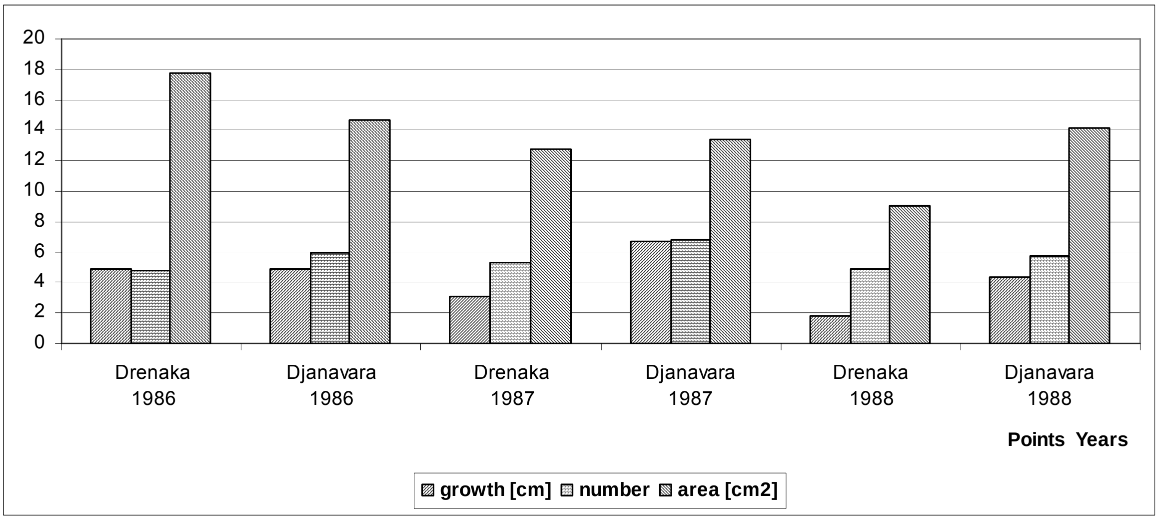
The comparison of the values from the two polluters shown that turkey oak responded to the pollution by substantial changes in the growth of the twigs - for Debelt (1988, 1989) and in the leaf area – for Devnya (1986, 1987), for Debelt (1988, 1989) (Fig. 3 A,B).

The carried out analysis proves that *Quercus cerris* can be appropriated as indicator only for industrial pollution presence, mainly through the indicators "growth of the annual twigs" and "area of leaves".

Quercus pubescens was studied under the air pollution in Devnya and Lead-zinc Works – Kurdzhali. The points of study are: Devnya: Drenaka and Janavara; Lead-zinc Works – at 1.00 km from the Works and near v. Jinzifovo – at 9.00 km far away from the pollution source.

The average values of the study of pubescent oak are shown on Fig 4. It was observed unidirectional reaction for the Devnya region – a decrease of the values for all of the indexes, more strongly demonstrated as regard to the area of leaves and the annual twigs' growth (Fig. 4 A). The leaf area in 1986 exceeded (120.8%), but to the end of the study it was reduced more strongly in 1988 reaching 64.1%. from control value. The annual twigs' growth from the points around Devnya was equal in the beginning (1986), whereas to the end of study it was strongly reduced to 45.2% (1987) and, particularly in 1988, to 42% in comparison with the control (Fig. 4 A). Bigger variation of the data was expressed as regard to the leaf area, especially in 1988, for other two parameters – in 1987 (Fig, 4 A).

A



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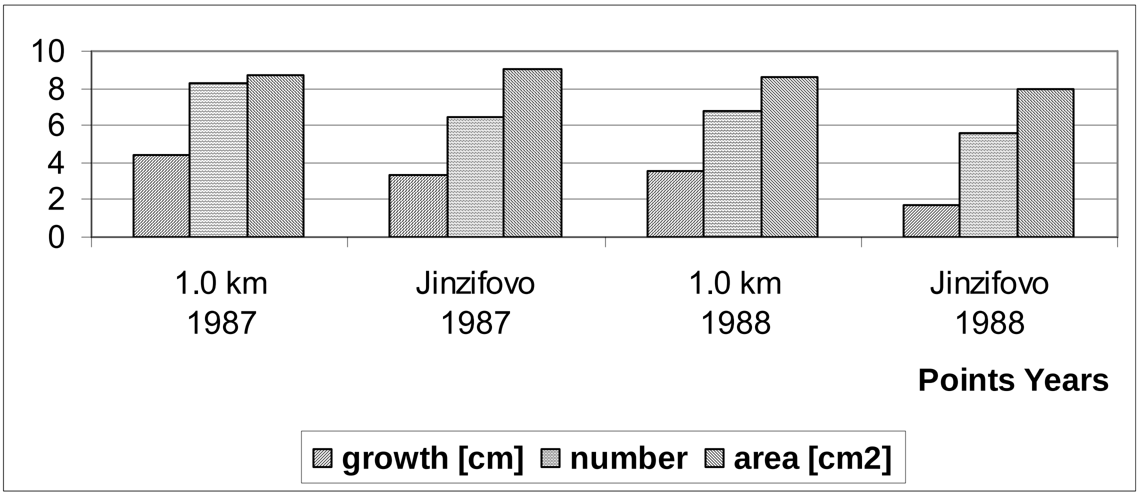


Fig. 4. Average values of the morphological parameters for *Quercus pubescens* Willd..in industrial polluted regions. (A) – Devnya; (B) Lead-zink Works, Kurdzhali. ...- Growth of annual twigs {cm}; ...- Number of leaves; (C) Area of leaves {cm^2}.

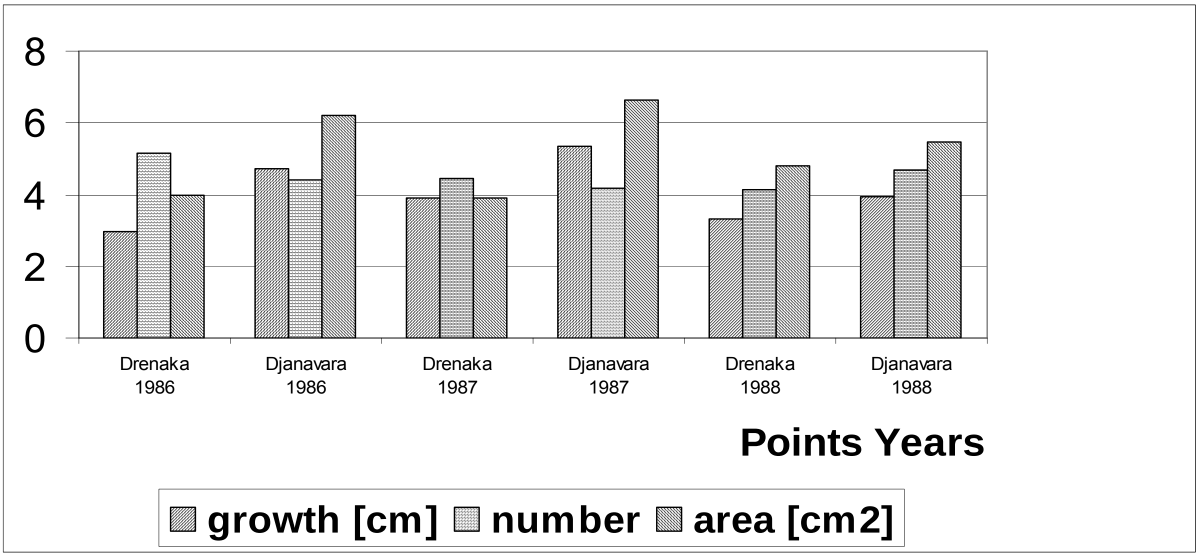
From the region around the Works near Kurdzhali the values of the growth of the twigs as the number of leaves on them exceeded the registered in the control (v. Jinzifovo) (Fig. 4 B). The essential difference in the twigs' growth data is shown in 1988, when the growth of the pubescent oak nearby the Works exceeded 205.8% the control, nevertheless that it was reduced in comparison with the data from the previous year (1987). The leaf area values are not unidirectional- in the first year the leaves were with area below (97.2%) the control, but to the end (1989) they overheated (107.2%) the control ones. The values of all of the morphological parameters were reduced in 1988 compare with the beginning of the study, but because of the diminution of the control values too, particularly in respect of the twigs' growth and leaf area, they remained higher than the controls.

The comparison the data from the both sources of industrial pollution showed that *Quercus pubescens* had higher annual twigs' growth and number of leaves in the region of Kurdzhali, but the leaf area was bigger in the specimens from Devnya (Fig. 4 A,B).

The carried out study proved that pubescent oak could be used for bioindication for presence of air pollution, but not for pollution specificity. From the studied morphological parameters the growth of the annual twigs is very essential, in lower degree – the number and area of leaves.

The study of *Carpinus orientalis* in the regions of Devnya and Burgas Combined Metallurgical Works v. Debelt includes 3 – for Devnya and 4- years period – for Debelt with two points (Devnya) and 3 points for Debelt -near the v. Cherni Vrah, v. Gabar and v. Rusokastro and the last of them was used as a control.

A



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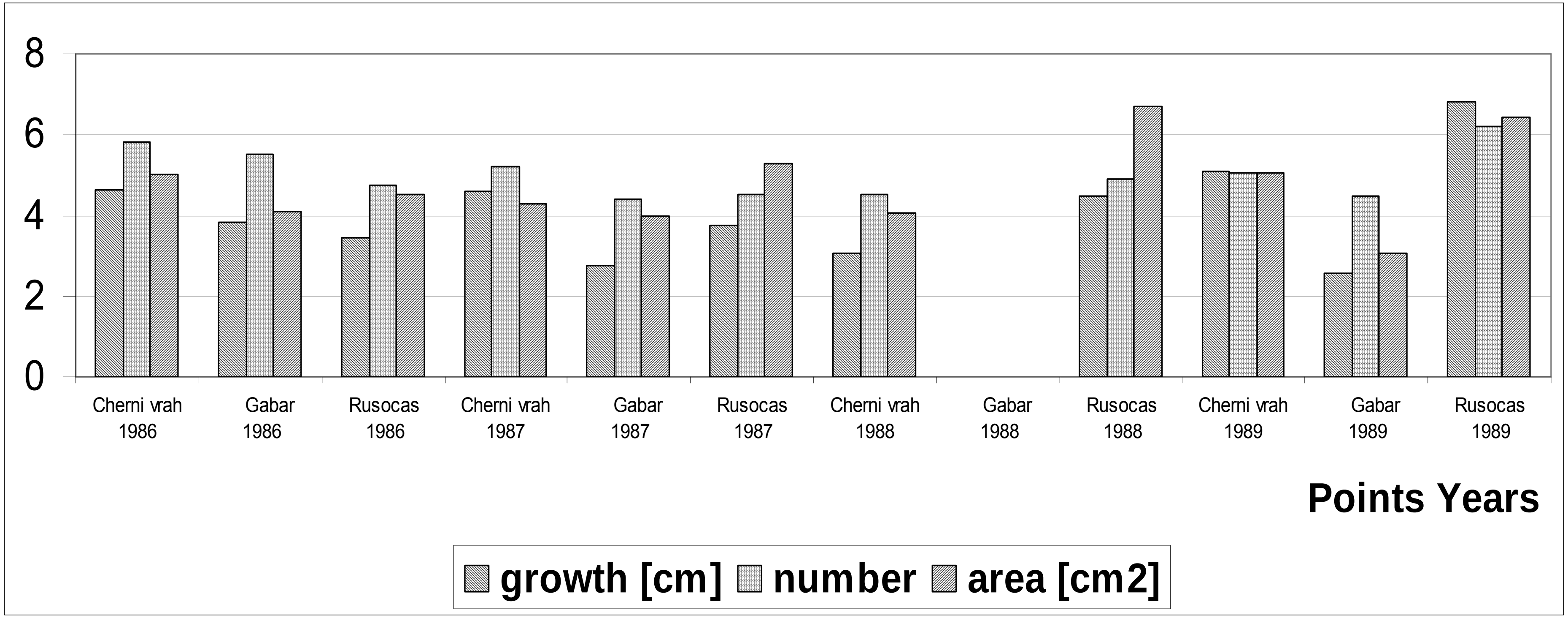


Fig. 5. Average values of the morphological parameters for *Carpinus orientalis* Mill. in industrial areas. (A) – Devnya; (B) –Burgas Works, Debelt….- Growth of the annual twigs {cm}; - Number of leaves; - Area of leaves {cm^2}.

values of these indexes from the polluted point in 1988 remained below, accordingly 84% and 88.2% as regard the controls. By growing of a greater number of leaves on the twigs, especially in 1986, *Carpinus orientalis* partially compensated the decreased growth and limited leaf area.

The study in the region around Debelt in the first two years has been carried out in the natural conditions, before the letting in exploitation of Stan-“300”. During the whole period of study essential differences in the annual twigs growth has not been observed in 1986, 1987 and at an initial level of pollution (1988) (Fig. 5 B) The linear growth of the twigs in the region of the v. Cherni Vrah is statistically different from the rest as in the first two years was higher – 134.2% (1986) and 130% (1987) than the control whereas to the end were below the control values from 68.9% (1988) to 74.7% for 1989. The lowest growth of the twigs is registered for the specimens near the v. Gabar, especially in 1989. Regarding “area of the leaves” the highest values, except the first year, have been registered for oriental hornbeam, growing nearby v. Rusocastro (Fig. 5 B). The pollution appearance in 1988 has affected on the studied parameters particularly in 1989 (growth of the twigs, number of leaves), for leaf area- in 1988 (Fig. 5 B).

The comparison of the data from the two industrial regions shows higher growth and area of leaves for the first two years in the oriental hornbeam around Debelt. In 1988, on the contrary, the values of these indeces were lower in Devnya. (Fig. 5 A,B).

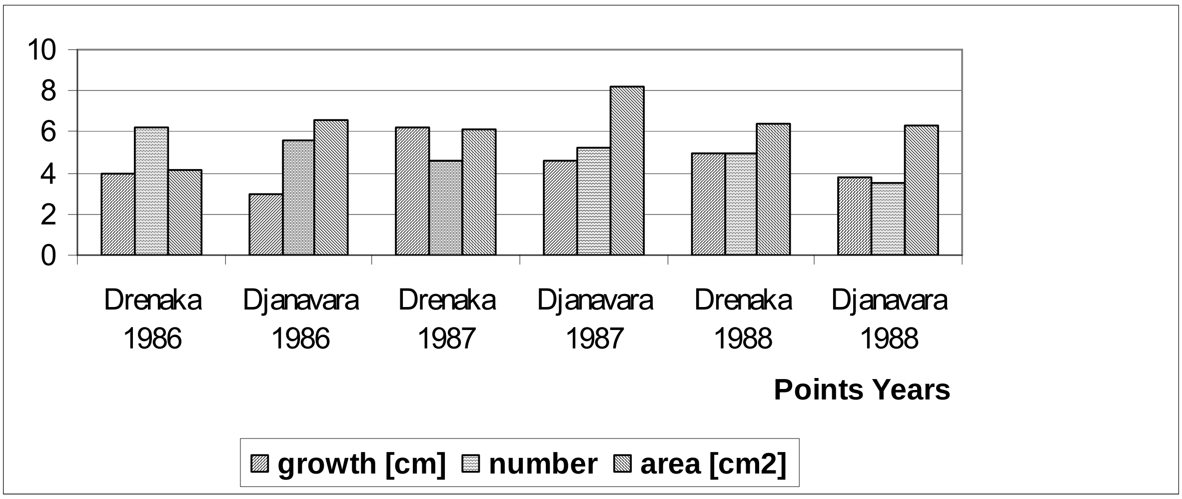
The results from the carried out analysis have shown that *Carpinus orientalis*, albeit lower growth and smaller leaf area, appears as a resistant to chemical (Devnya) as well as metallurgical type of pollution (Debelt). For the goals of the bioindication essentially important are the “area of the leaves” and “linear growth of the annual twigs”. The number of leaves is essential index only in 1988 when apart pollution, as factor retarded the growth and development of the species, was the strong drought. The medium position of the control (v. Rusocastro) regarding the twigs’ growth and number of leaves on them (1987), as for leaf area (1986) proved that, except pollution, other environmental factors in the region, mainly climatic, have influenced on the growth and development of that species.

Compare to *Quercus cerris*, oriental hornbeam in the region around Metallurgical Works in Debelt demonstrated a steady development (by higher twigs’ growth and greater number of leaves, mainly to the end of study) and high degree of adaptation to the ecological conditions in the studied area (KURTEVA, BONDEV 1997). As pay attention on the high drought-resistance of *Carpinus orientalis*, that’s a confirmation for progressive droughts of the region in the future, which will lead to degradation of the oak forests and their replacement with *Carpinus orientalis* communities.

For the *Crataegus monogyna* specimens of in the region of Devnya and UMPC–Pirdop the duration of study includes 3- (for Devnya) and 2- years period (for UMPC–Pirdop) with points: Devnya- Drenaka, Djanavara; Pirdop – 0.2 km, h. Kaliman, K (control).

The results from the study are presented on Fig. 6. For the Devnya region the twigs’ growth exceeded the control value during the whole period of study, in the interval: 131.3% (1988) – 136.5% (1986) (Fig. 6 A). The number of leaves was higher

A



B

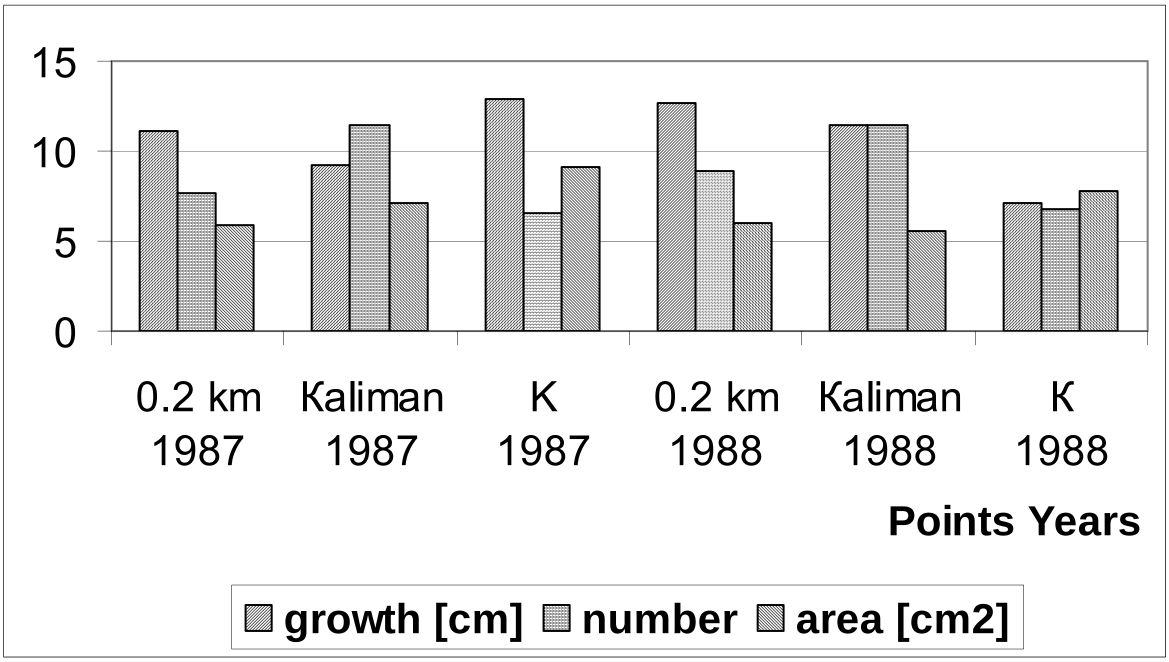


Fig. 6. Average values of the morphological parameters for *Crataegus monogyna* Jacq. in industrial areas. (A) – Devnya region; (B) UMPM-Pirdop; . – Growth of the annual twigs {cm}; .. - Number of leaves on the twigs; - Area of leaves {cm^2}.

compare to the control in the beginning (1986) – 112.2% and the end of study (1988) – 141.3%, but below the control one for 1987. More significant variation in the values was outlined as regard to the twigs' growth (1987), area of leaves (1986, 1987), and the number of leaves (1988) (Fig. 6 A). Leaf area in the first two years was below the control, correspondingly 62.6% (1986) and 75% (1987) while in the end of study reached the control. It was outlined a partial compensation of the reduced leaf area with higher growth of the twigs (1987) or greater number of leaves (1986) compare to the control (Fig. 6 A). The closeness of the values regarding leaf area (1988) is connected not only with slight increase in comparison with the values from the previous year, but mainly with the strongly decreasing of the control data. The similar situation was observed and represented for *Carpinus orientalis* there, but in respect of the twigs' growth (Fig., 5,A). The values diminution in the control point (Janavara) indirectly prove as for the influence of industrial pollution in this quite remote from the polluter region, as the interference of other environmental factors, especially strong drought on the species growth and development in this point.

The survival of *Crataegus monogyna* in Devnya industrial region is due to the higher growth of the twigs and greater number of leaves, but with decreased area compare to the control version.

In the region of UMPM – Pirdop The species response to the pollution in 1987 and 1988 is quite different. So, in 0.2 km from the polluter common hawthorn in 1987 had lower twigs' growth (85.9%) and decreased leaf area (64.3%) compare to the control, but as compensation developed higher number of leaves (Fig. 6 B). In the end of study the growth of the twigs strongly exceeded (179%) the control one, while the leaf area retained smaller (77.3%)(Fig. 6 B). Only the number of leaves during the two years was higher than the control in the interval: 116.8% (1987) – 131.8% (1988) as partially compensation mainly of the quite limited leaf area.

The comparison of data from the two polluters showed higher twigs' growth and bigger number of leaves in the specimens around Pirdop, but the differences as regard of leaf area are minimal (Fig. 6 A,B)..

The obtained results of *Crataegus monogyna* study confirmed that the species could be used as pollution bioindicator, but for presence only. From the morphological parameters the leaf area and, in lower degree, number of leaves are with essential importance for the aims of the bioindication.

CONCLUSIONS

The carrying out analysis proves that the studied tree and shrub species can be used for bioindication of the industrial pollution in the studied regions.

All of the investigated species can be applied as indicators only for pollution presence, without to determine its specificity.

Among the studied species as indicators more suitable for the pollution in the Devnya industrial region are determined *Robinia pseudoacacia, Quercus pubescens, Carpinus orientalis* and *Crataegus monogyna*, whereas *Quercus cerris* can be used with a priority for the region around Burgas Works in Debelt.

The three morphological parameters are bioindicators as the area of leaves is the most significant index for all of the species. The "growth of the annual twigs" is defined for *Robinia pseudoacacia*, *Carpinus orientalis*, *Quercus pubescens* and *Quercus cerris*, while the "number of leaves on the annual twigs" - for *Crataegus monogyna*, *Carpinus orientalis* and *Quercus pubescens*.

The medium position of the control variant for *Carpinus orientalis* (v. Rusocastro) regarding the twigs' growth (1987) as well as the leaf area (1986) proved that, except pollution, other environmental factors in the region, mainly climatic, have influenced on these parameters.

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