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THE INFLUENCE OF SUBSTRATUM pH LEVEL ON GROWTH OF SEA BUCKTHORN (*HIPPOPHAË RHAMNOIDES* L.) OF THE EXTERNAL SPOIL BANK OF THE BEŁCHATÓW BROWN COAL MINE

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Abstract. Sea buckthorn (*Hippophaë rhamnoides* L.) is a pioneer species, well adapted to colonize soil-less substrata. It features rapid growth, due to symbiosis with nitrogen-fixing actinomycete *Frankia*. This species is recommended for reclamation of degraded lands, especially soil-less areas endangered by erosion. This work investigates the influence of substratum acidity (pH(KCl)) on growth of sea buckthorn on the external spoil bank of the Bełchatów Brown Coal Mine in central Poland. First year survival and subsequent growth of planted specimens was strongly dependent on substratum acidity. The range of pH variability tolerated by sea buckthorn on spoil bank was comparable with the range observed in natural conditions. The best growth (and potentially the best ability to stabilize substratum) was observed on neutral substrata pH(KCl) 6.61-7.2. while the worst on very acid substrata (pH(KCl) 3.51-4.5). The pH level of substratum could be very useful diagnostic feature to assess suitability of sea buckthorn for substratum stabilization.

Key words: substratum acidity pH(KCl), sea buckthorn, substratum stabilization, spoil bank

INTRODUCTION

Sea buckthorn (*Hippophaë rhamnoides* L.) is a light demanding, frost resistant, species stabilizing substratum by numerous aerial shoots developing from creeping roots. This species has rather moderate requirements as far as fertility of substratum is concerned. Sea buckthorn can fix atmospheric nitrogen by root nodules due to symbiosis with nitrogen-fixing actinomycete *Frankia* [Benson at al. 2004]. This shrub is recommended for reclamation of degraded lands, especially soil-less areas endangered by erosion [Kapuściński 1978, Seneta 1978] including newly created dumps [Zieliński and Nowak 2004]. On this account for a long time it has been used to slopes stabilization of

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ground structures such as spoil banks (external or internal) connected with lignite mines [Knabe 1964] and similar structures [Matache et al. 2003].

Scientific reports suggest that in spite of relatively moderate requirements to soil fertility, sea buckthorn in nature retreats from locations where soil pH levels drops below 5.5 [Westhoff 1947, after Rieck 2000]. Investigations of Dramer [1952, after Kapuściński 1978] seem prove this observations. Research of natural populations of sea buckthorn on Polish coast [Kapuściński 1978] demonstrate occurrence of this species on soils with pH 4.7. Cited papers concern relation between occurrence of sea buckthorn and soil pH level. The influence of soil pH level on growth of sea buckthorn however, was less investigated, although it could be of practical use.

The selection of species for reclamation of lands endangered by erosion should point out plants capable for fast substratum stabilization. A practical hint for species selection, especially on soil-less lands, could be pH level, which is usually vital for the fast plants growth and successful stabilization. This paper presents the outcome of investigations on the influence of substratum pH level on sea buckthorn growth on the external spoil bank of the Bełchatów Brown Coal Mine.

STUDY AREA

The external spoil bank of the Bełchatów Brown Coal Mine was build in years 1975-1994 with materials taken from the pit to expose coal field "Bełchatów". It is placed in the central part of Poland (51°12'39"N, 19°25'56"E). In this region the vegetational period lasts 200-210 days, the mean annual temperature is 7.6ºC and precipitations is 600 mm [Operat glebowo-siedliskowy... 1989]. The total area of this external spoil bank is about 1500 ha and its relative height varies from 126 to 180 m. Slopes of spoil bank have area 1165 ha (79%) and the top plateau has area 318 ha (21%). The spoil bank is built of the Quaternary and Tertiary formations. The Quaternary is represented mainly by fluvioglacial sands, silts, varved clays, boulder clays, lacustrine chalk, peat, and gyttja, while the Tertiary by the loose rocks (sands and gravels) alternately with compact ones (clays, silts, and lacustrine chalk) [Pająk at al. 2004].

The external spoil bank was almost entirely reclaimed in forest direction. Immediately after final formation of spoil bank surface trees and shrubs ware planted on 74% of spoil bank area. During that process sea buckthorn was planted mostly in areas especially endangered by water erosion i.e. near or on the edges of subsequent terraces of spoil bank [Krzaklewski and Wójcik 1995].

MATERIAL AND METHODS

Field works were conducted mainly in autumn 2004. Two experiments were made: first an assessment of the height of sea buckthorn colonies growing on substratum with different pH levels and second: an assessment of the first year growth of sea buckthorn planting stock planted on rather lower pH substratum.

In the first experiment only colonies in favourable growing conditions were measured, i.e. those which development was not constrained by neighbouring specimens of another tree species or other obstacles (roads, ditches etc.). For each colony the highest shoot was searched out in the central part of clump and its height was measured. After that the shoot was cut at the ground level and its age was estimated by annual rings counting. This age was accepted as the age of the whole colony. The substratum pH level was measured at the distance of 0.5 m from the central shoot, at the depth of 0.3 m. The relationship between age and height (h) was expressed by logarithmic curve with the formula $h = a \cdot \ln(age) - b$, where a and b were coefficient empirically assessed to fit the curve to the data. Due to rather large span of pH levels in spoil bank substrata the relationship between age and height of sea buckthorn was analyzed for five separate substratum pH classes. The classes were adopted from classification commonly used in Polish forestry [Instrukcja urządzania... 2003] as follows: very acid substratum pH(KCl) 3.51-4.5, acid substratum pH(KCl) 4.51-5.5, slightly acid substratum pH(KCl) 5.51-6.6, neutral substratum pH(KCl) 6.61-7.2, slightly alkaline substratum pH(KCl) 7.21-8.0.

In the second experiment the planting stock was of vegetative origin. The two years old sprouts with roots were acquired from external parts of sea buckthorn colonies and planted in autumn 2003 on rather acid substratum pH (1.75-6.01), devastated by water erosion. In autumn 2004 by means of visual assessment each plant was count among one of six growth classes. Following classes were used: A – plant did not start vegetation, B – plant started vegetation and died, C – plant survived and has leaves shorter than 1 cm, D – plant – plant survived and has leaves length between 1.1 cm and 2 cm, E – plant – plant survived and has leaves length between 2.1 cm and 3 cm, F – plant – plant survived and has leaves longer than 3.1 cm.

For ten randomly selected plants from each growth class, substratum pH(KCl) level was measured at the distance of 0.3 m from the plant, at the depth of 0.3 m. All the measurements were made with an electronic device ELMETRON CP-104. This pHmeter can measure pH level in the range from 0 to 14. Readings from this device should be interpreted as pH(KCl) measure.

RESULTS

In the first experiment the height and age of central shoot was determined for 140 clumps of sea buckthorn. The age of investigated specimens varied from 2 to 12 years, and measured substratum pH levels on which they grew fluctuated from 3.87 to 7.85. The height measurements records and fitted logarithmic curves were presented on Figures 1 a-e. Determination coefficients (R^2) describing the fit of logarithmic curves to the data reached high values in the range from 0.80 to 0.97. The shape of fitted logarithmic curves suggests that after seventh year of life the rate of high increment of central shoots in clumps of sea buckthorn decrease.

The comparison of fitted logarithmic curves presented on Figure 1 f suggests that growth of sea buckthorn bushes was the worst on very acid substratum (pH(KCl) 3.51--4.5). As the pH level of substratum increased the height of shoot attained at the same age increased. The largest height in given age was attained by shoots growing on neutral substrata pH(KCl) 6.5-7.2. Further increase of substratum pH level caused decrease of shoot height. On slightly alkaline substrata the height of sea buckthorn was similar to those from slightly acid substrata.

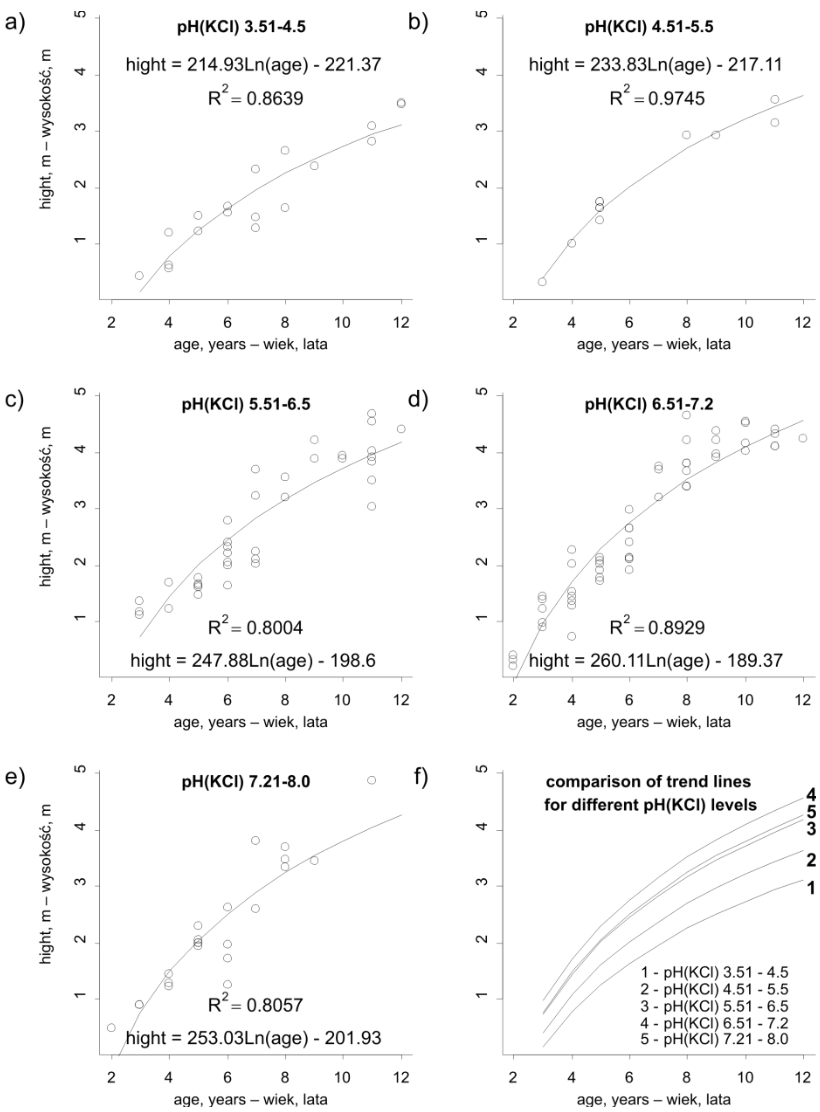

Fig. 1. Relations between age and height of the highest stem in colonies of sea buckthorn (*Hippophaë rhamnoides* L.) observed on substrata with different pH(KCl) levels on external spoil bank of the Bełchatów Brown Coal Mine

Rys. 1. Zależność pomiędzy wiekiem a wysokością najwyższego pędu w koloni rokitnika (*Hippophaë rhamnoides* L.) obserwowana na podłożu o różnym pH(KCl) na zwałowisku zewnętrznym KWB Bełchatów

In the second experiment the development of 305 sea buckthorn plants, planted in autumn 2003, was assessed in June 2004. Additionally 55 measurements of substratum pH level were made near randomly selected plants. The results of these observations are

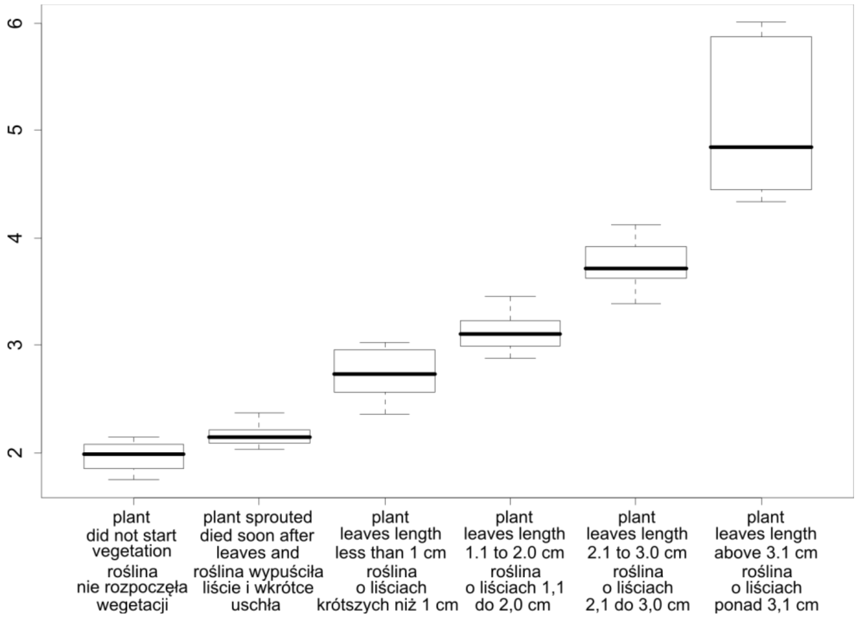

Fig. 2. Relation between substratum pH(KCl) level and growth of two years-old sea buckthorn (*Hippophaë rhamnoides* L.) planting stock form vegetative propagation observed on very acid substrata eroded by water on external spoil bank of the Brown Coal Mine Bełchatów. Solid thick lines inside the box depict mean value, and the thin lines under an above the box depict respectively minimum and maximum value of observed pH(KCl) level

Rys. 2. Zależność pomiędzy pH(KCl) podłoża a wzrostem dwuletnich sadzonek z odrośli korzeniowych rokitnika (*Hippophaë rhamnoides* L.) obserwowana na zakwaszonym podłożu erodowanym przez wodę na zwałowisku zewnętrznym KWB Bełchatów. Ciągła i gruba linia wewnątrz prostokąta oznacza wartość średnią, a cienkie linie ciągłe poniżej i powyżej wyznaczają odpowiednio wartość minimalną i maksymalną zaobserwowanego poziomu pH(KCl) utworów podłoża

presented on Figure 2. For plants which did not start vegetations (class A) the mean pH substratum level was about 2, and for those which died in spring (class B) pH level was not very much higher. The mean pH level of the weakest survivors (class C) was about 2.7. As the pH level of substratum was increasing the overall performance of plants was better. The best developed plants (class E) were observed on substrata with mean pH level of 5.

DISCUSSION

During reclamation of external spoil bank the sea buckthorn planting stock was placed in areas especially endangered by water erosion. The substratum pH level was not considered as the localization factor. The survival of sea buckthorn plants to the year 2004 was influenced by many factors. The substratum pH level was probably one of the most important one. Observed on external spoil bank range of pH levels of substrata on which the sea buckthorn grew was even larger than reported for natural populations in the Polish Baltic coast [Kapuściński 1978]. Probably the observed range of pH level approached the overall toleration limits for this species. The observations of plants planted on rather acid substrata (second experiment) suggest that pH level above 2.5 is critical to survival. Specimens planted on substrata with pH level between 2.5 and 4 had distinctly shortened leaves in comparison to plants in Polish natural populations [Kapuściński 1977] and showed weaker growth. Their further survival was rather dubious. Only on the substrata with pH level above four the planted specimens featured leaves longer than 3 cm and normal development. Probably sea buckthorn specimens planted during reclamation survived and developed into colonies only in favorable (in term of substratum pH level) conditions. The majority of younger investigated sea buckthorn colonies (in first experiment) were of natural origin. They developed from seeds in places favorable for sea buckthorn. It can be assumed that the lowest (3.87) pH (KCl) value of substratum on which clumps of sea buckthorn were measured is close to minimal value tolerable by this species yet lower than was observed in natural conditions – 4.3 [Kapuściński 1978]. The maximum substratum pH level below sea buckthorn colony was 7.85. This value was higher than the highest value (7.45) observed in natural conditions in Poland [Kapuściński 1978] and not much lower than maximum value (8.1) reported by Pearson and Rogers [1958] for cliff of Kent.

The logarithmic curves compared on Figure 1 f suggest that there is a distinct influence of substratum pH level on height of shoots of sea buckthorn of the same age. It is possible that differences in substratum fertility can influence this relationship. The coefficients of determination (R^2) value given for particular curve suggest that model based on age for different pH level can explain much (80-97%) of variability of measured heights.

The low substratum pH level can influence both availability of nutrients in soil solution (e.g. influencing nutrients diffusion) and ability of plants to absorb nutrients. Sea buckthorn seems especially viable to such influence also for another reason. This species is commonly suggested for reclamation of soil-less substrata due to its ability of nitrogen fixation by root nodules due to symbiosis with nitrogen-fixing actinomycete *Frankia* [Benson et al. 2004]. Unfortunately this ability is seriously constrained by lower soil pH level as shown by investigations carried out in natural areas. Newly established sea dunes with relatively high pH level are colonized by sea buckthorn, which in such conditions generate numerous root nodules – places for symbiotic organisms. In the course of dune ageing pH level usually decrease. The symbiosis with *Frankia* as well mycorrhizas are fading. In such conditions sea buckthorn roots are endangered by pathogens, especially by nematodes. Complex changes in soil fauna and flora, caused by pH level changes can led in natural conditions to local dieback of sea buckthorn population [Rieck 2000].

Many authors [Zalewska 1955, Seneta 1978] stress that sea buckthorn prefers soils with high calcium carbonate content and recedes from places where this compound was washed out during soil formation process [Zalewska 1955, Krupiński 1992]. Substrata in spoil banks sometimes have tendency to become more acid in the course of time due to oxidation of sulfur-containing chemical compounds. This process leads to faster and stronger acidification of substratum than natural processes on ageing sea dunes. It could be an additional factor limiting suitability of sea buckthorn for reclamation of some degraded lands.

CONCLUSIONS

The occurrence of sea buckthorn colonies on external spoil bank of the Bełchatów Brown Coal Mine is influenced by substratum pH level.

Observed on external spoil bank range of pH levels of substrata on which the sea buckthorn grew is similar to overall limits which this species tolerates in natural conditions.

Sea buckthorn colonies of age between 2-12 years were the highest on soil-less substrata with pH level between 6.52 and 7.2, and the lowest on very acid substrata.

The pH level could be very useful diagnostic feature to assess suitability of sea buckthorn for substratum stabilization.

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WPŁYW pH UTWORÓW PODŁOŻA NA WZROST ROKITNIKA (*HIPPOPHAË RHAMNOIDES* L.) NA ZWAŁOWISKU ZEWNĘTRZNYM KOPALNI WĘGLA BRUNATNEGO BEŁCHATÓW

Streszczenie. Rokitnik *Hippophaë rhamnoides* L. jest gatunkiem pionierskim, przystosowanym do kolonizacji podłoża bezglebowego. Odznacza się szybkim wzrostem, który zawdzięcza między innymi symbiozie z promieniowcami z rodzaju *Frankia* wiążącymi azot z powietrza glebowego. Gatunek ten może być przydatny w procesie rekultywacji terenów zdegradowanych, szczególnie do stabilizacji podłoża na zboczach budowli ziemnych. W pracy przeprowadzono badania wpływu kwasowości podłoża (pH(KCl)) na wzrost rokitnika w warunkach panujących na zwałowisku zewnętrznym KWB Bełchatów. Przeżywalność sadzonek rokitnika i ich dalszy wzrost okazały się bardzo silnie związane z pH utworów podłoża. Zakres pH tolerowany przez rokitnik rosnący na zwałowisku był podobny do obserwowanego na siedliskach naturalnych. Najlepszy wzrost i potencjalnie najlepszą stabilizację podłoża obserwowano przy odczynie pH obojętnym, natomiast najsłabszy wzrost zaobserwowano na podłożu silnie kwaśnym. Poziom pH utworów podłoża może być przydatną cechą diagnostyczną, pozwalającą określić możliwość zastosowania rokitnika do stabilizacji podłoża.

Słowa kluczowe: pH(KCl) podłoża, rokitnik, rekultywacja, stabilizacja podłoża, zwałowisko

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