POPULATION BIOLOGY OF *AGROPYRON REPENS* (L.) P. BEAUV. AROUND THE COPPER SMELTER LEGNICA

TERESA BREJ

Department of Botany and Plant Physiology
Agricultural University, Cybulskiego 32, 50-205 Wrocław, Poland

(Received: April 25, 2000. Accepted: August 25, 2000)

ABSTRACT

The present paper constitutes a background for the properties of couch grass tolerance for heavy metals previously recorded by the author. The tolerance for lead, zinc, copper and cadmium were described in couch grass on sites in the vicinity of the copper smelter Legnica. Most of the now presented results come from four-year field investigations, concerning four couch grass populations growing at different distances from the emitter. The over 50 year activity of the smelter affected specifically the traits and properties of the couch grass populations and their dynamics. This is expressed in the differentiated production of below and above ground biomass of couch grass and birth of aerial shoots. Further, recorded was also a different dynamics of origin and growth of rhizomes, and a retarded phenological development in populations localised nearest the smelter. The diverse population dynamics is expressed in different parameters, presented in the life tables. A change in growth strategy of couch grass, from querilla into phalanx, in result of ionic stress, was recorded in populations situated in the vicinity of the smelter.

KEY WORDS: *Agropyron repens*, population dynamics, birth, mortality, life tables, phenology, influence of heavy metals.

INTRODUCTION

Couch grass *Agropyron repens* (L.) P. Beauv. = *Elymus repens* (L.) Gould*, as one of the most arduous weeds of the world (Radosevich and Holt 1984) was the subject of many investigations, particularly on individual level. Its individual biological and physiological properties aroused since long great interest of agronomists, who wanted to learn comprehensively the biology and autecology of couch grass in order to fight it efficiently (Kraus 1912; McIntyre 1965 and further ones; Håkansson 1967, 1968, 1982; Bojarczyk et al. 1979; Neuteboom 1981; Westra and Wyse 1981; Wesołowski 1983; Rola 1985; Malicki and Berbec 1986; Pawłowski and Bojarczyk 1986; Rola et al. 1988; Marshall 1990; Pałys 1990). Ample results of laboratory and field investigations on seed production, germination and seedlings development in couch grass were presented by Williams (1970, 1973) and Williams and Attwood (1971). These works and the data devoted by Palmer (1958) to the biology and ecology of rhizomes, and the later ones by McIntyre (1987) and McIntyre and Cessna (1998) make the basic information sources on the, frequently striking, properties of the underground shoots of couch grass (rhizomes, roots, buds). A synthetic approach to couch grass biology is presented in papers by Palmer and Sagar (1963), and Werner and Rioux (1977). Population studies on couch grass were so far almost exclusive-

ly carried out on created-experimental, glasshouse or garden populations (Tripathi and Harper 1973; Sagar and Mortimer 1976; Harper 1977; Mortimer 1983; Cousens and Mortimer 1995). The precision of these experiments is not questioned, but it should be mentioned that using them for drawing conclusions pertaining to natural populations, occurring in various field conditions is difficult. The lack of field data for natural couch grass populations is felt both by biologists and agronomists. There are also no data on couch grass regarding its clonal growth and the enormous potential of vegetative growth (both in above and underground shoots) (compare, e.g. Marshall and Price 1999). This lack is obviously connected with methodical difficulties caused by this plant as an object for population investigators. This is caused by the difficulty to reach to the extremely rich underground structure, the overlapping generations of aerial shoots and their clonal structure and the periodically low generative reproduction. From among recent works using the clonal potential and vegetative growth of couch grass, worthy of notice are the investigations by Ryel et al. (1996), opening possibilities to use this plant as an efficient roadside grass. The present investigations refer to an earlier work (Brej 1998), distinguishing couch grass populations according to the varied sensitivity to heavy metals. The mentioned paper presents experiments localised in glasshouse and laboratory. The investigations were carried out mainly in field. This was also the area around the copper smelter Legnica, which creates stressing conditions for plant growth, a terrain contaminated for over 50 years by the

*Terminology according to Mirek et al. 1995.

smelting works. The main purpose was to find out whether the previously distinguished, spontaneously expanding populations, of various tolerance to heavy metals, show different ecological properties. The investigations were fixed on reproduction dynamics, which leads to clonal growth and complicated above-ground and underground structure of couch grass. The results of the investigations, depending on analysis of many population parameters, confirm the previously observed separateness of populations growing in close vicinity of the copper smelter. The author hopes that apart of the presented results concerning population dynamics of couch grass, also the practical aspect of the investigations, depending on using resistant populations for remediation and reclamation purposes will be noticed.

MATERIAL AND METHODS

Most of the investigations were based on field experiments. In the years 1991-1994 in field conditions analysed were four couch grass populations localised at different distances from the emitter (copper smelter). In the zone of dominating winds, and closest to the smelter (800-5000 m), localised were the populations A and B (Fig. 1). Population C was situated on the opposite side (lee side) of the emitter at a distance of 1500 m. The control population (K) was a couch grass site localised about 15 km south-westwards from the smelter. The levels of heavy metals concentrations in soil and plants on the mentioned sites are given in a previous paper (Brej 1998). For permanent observations of selected population characteristics delimited were 18 constant squares (for every population: A, B, C, K), well marked in the terrain, which were investigated each year during the vegetation season (with a frequency of every 4-6 weeks). On all the plots couch grass occurred in natural monocultures as a result of fallow land expansion. The few other species present on the permanent plots were removed from them before and during the experiment. The plots were selected according to similar density, age of populations and rhizome presence. The biomass of the above and underground parts of couch grass was expressed as dry weight of shoots and rhizomes. Because of

poor earing during the period of investigation, in populations A and B there was no need to perform measurements of weight of the generative parts. Because of methodological difficulties the roots of couch grass could also not be taken into account in the experiments. The roots can only partly be taken from the soil. Moreover, it is difficult to separate the roots from rhizomes penetrating the soil at different levels and roots developing directly under the joint of tillering. Observations and measurements of couch grass rhizomes were performed in the particular populations by digging up profiles; this enabled to estimate the dynamics of the underground parts of the plants (length of rhizomes, number of internodes, number of buds).

The synthetic picture of dynamics of the investigated *A. repens* populations are the life tables, made according to the model by Sagar and Mortimer (1976) with own modifications. Out of necessity the phenological observations have been limited to the early developmental stages of couch grass. The irregular time of duration or lack of generative stages on plots near the copper smelter prevented the complex comparison of all the phases of development. For selecting permanent plots, taking samples, and for other ecological procedures of investigation used were methods described in handbooks by Moore and Chapman (1986), Hendry and Grime (1993), and Falińska (1996).

RESULTS AND DISCUSSION

Age stages of couch grass

As noticed by many investigators (e.g., Håkansson and Wallgren 1976), couch grass has no real innate dormancy in any season of the year. This applies so to the, poorly known in this plant, generative phase, as the better known development of the vegetative system. As results from the old, but accurate works by Williams (1971) and Williams and Attwood (1971), the course of the generative phase of couch grass is capricious and depends upon many factors. The appearance of seedlings may take place from August until the end of autumn during the whole period of coming to ear and running to seed. Earing of

Fig. 1. Field localization of four *Agropyron repens* populations growing under different influence of the copper smelter. A, B, C – contaminated populations, K – control population. Isolines showing theoretical copper precipitation ($t/Cu/km^2/year$), after Fabiszewski et al. (1983).

couch grass has been rarely observed during my own observations, both close to the copper smelter, and on the control surface. An intense earing and running to seed took place in 1994 on almost the whole investigated area, and included also plots localised closest to the copper smelter (see: Fig. 2, Brej 1998). Maybe, this was the effect of the dry and rainless autumn, which might – according to Williams (1971) and Håkansson (1982) – stimulate earing and running to seed. However, in literature there are still no convincing data on factors stimulating the appearance of the generative phase of couch grass. There is also no agreement on power and energy of seed germination in various periods of its life (see: Werner and Rioux 1977). The few seedlings recorded during the investigation, coming from the current fruiting, as well as, the surface and the buried seed bank, confirm the existence of the generative phase. For occurrence of couch grass expansion in the investigated area, the generative reproduction, apart of the hidden effect, genetic in character, (self-sterility) is of minor influence. The extent and viability of couch grass, here and elsewhere, is decisive for its reproduction and vegetative potential. Therefore the age stages of couch grass growing in the vicinity of the copper smelter do not include its generative phase, the investigations of origin and fate of which failed to be followed in detail.

The juvenile stage (a), which originated in a vegetative way, came into existence in result of rhizome fragmentation, having a unit with one or more buds (Fig. 2). The juvenile stage is visible during the whole year, and in autumn can be mistaken with seedlings. Each season of the year – strong winters excluded – is suitable for disintegration of rhizomes or spreading of their fragments by animals. These rhizomes may initiate aerial shoots and new rhizomes. The dormancy of little rhizome fragments is short in duration, sometimes only several days. Particularly dur-

ing spring and summer stimulation of growth takes place, heading towards a more leafy immature stage (b) (Fig. 2). With existence of favourable trophic and climatic conditions there occurs the next, advanced stage (c), more leafy and producing the first tillers, initiating also new rhizomes, temporarily nearer the primary shoot. The typical summer stage consists of premature (d) and mature (e) plants, rapidly increasing the number of tillers and new rhizomes. The latter, through new ramifications, both upwards and laterally, form new underground shoots and multi-layer rhizome structures reaching far and deep beyond the area of the parent plant. At the same time the parent plants produce subsequent tillers from underground buds (joints of tillering). Senile stages (f), arising from disintegration of rhizomes, are formed during the whole year, also during mild winter, initiating the juvenile, above-ground shoots. The strong disintegration of rhizomes can indirectly influence the increase of competition between aerial shoots, but this phenomenon could be observed only in the control population (K). Thus, the particular age stages are in field not precisely separated and overlap one another.

In grasses, similar stages are described by Håkansson (1982), Zhukova and Ermakova (1985). However, the determination of age in rhizomes and aboveground tillers in perennial grasses is very difficult or even impossible, unless special methods of cultivation are used. The average clone age in polluted conditions near the copper smelter is 3-4 years, with oldest clones situated on plots closest to the smelter reaching 5-7 years. Their disintegration may depend on „saturation” of rhizomes with toxic substances – heavy metals – though it is difficult to prove this observation by measurement. At any rate, the disintegration of clones in those conditions depends neither on climatic factors, nor on season of the year. Attempts to use data on age and way of growth serve for creation of classification systems of weeds and clonal plants. Håkansson (1982) included couch grass among wandering plants and among weeds with a strong shallow rhizome system, instead according to Klimeš et al. (1997) couch grass belongs among plants with stem-derived organs of clonal growth and to the *Aegopodium podagraria* type with hypogeotropic stems > 10 cm in length. The latter view should be supplemented by the observation that – because of the plant's importance – this should be rather the type *Agropyron* with an eventual participation of *Aegopodium* and other plants. The knowledge of clonal architecture of couch grass, in connection with local conditions, facilitates the fight against weeds, particularly the mechanical one. On fields lying fallow for even a short term there develops a strong clonal structure (above and underground), which hinders the later fight against couch grass.

Birth and population mortality

The specificity of couch-grass growth and development creates certain difficulties in investigating birth and mortality of below and above ground rhizomes. Without using special techniques of cultivation (e.g., large, transparent containers) it is impossible to follow the mentioned population processes in couch grass rhizomes. The results are presented only for the aerial shoot system (Fig. 3) for four years of investigations, and for two decidedly different populations (A and K). These data are however burdened with certain simplifications, but despite of the incomplete material they could be presented in the form of reliable diagrams. A part of the simplifications resulted from difficulties in separating the aerial individuals. The still alive, but already dying rhizomes of couch grass have primordia of

Fig. 2. Age stages of couch grass reproducing vegetatively. a – juvenile, b – immature, c – advanced, d – premature, e – mature, f – senile. Some of the drawings according to Håkansson (1982).

Fig. 3. The four-year pattern of birth and mortality of aerial shoot system in two populations of couch grass. K – control population, A – polluted population.

shoots, localised in or beyond the leaf sheaths. The simultaneous rising of new rhizomes impedes the classification of old ones, of which, moreover, not all die before and during the winter. The analysis of the included diagrams allows to conclude, that the control population K shows a distinct seasonal birth periodicity, the process of which decreases significantly during autumn, winter and spring, and increases rapidly during summer. The fight against couch grass should be conducted in accordance with this rhythm. This phenomenon is less clear for population A (closest to the smelter), which does not show such seasonal fluctuations in the birth process. The birth number is here considerably lower and more stabilised in the particular seasons. The damping of birth is distinctly influenced by the nearness of the smelter, where, apart of couch grass, only several species of higher plants resistant to heavy metals are recorded (Brej 1983; Rebele et al. 1993; Fabiszewski et al. 1986). In the control population also mortality is subjected to seasonal fluctuations, which usually – though not always – increases in autumn and winter. The mortality in population A is almost free of such yearly and seasonal fluctuations, and maintains to some extent in state of stable balance. The regulation of population size takes place both in populations A and K, probably as a result of asymmetrical and intraspecific competition (Weiner and Thomas 1986), typical for plant monocultures and caused by variability of size in different individuals. The mechanism of resistance in population A exposed to stress conditions, depends therefore upon slight, but equalised births of above-ground shoots and upon a relatively small mortality not subjected to greater oscillations. Returning to the earlier published results (Brej 1998) related to couch grass, as well as, to the, growing in the vicinity of the smelter, field bindweed *Convolvulus arvensis* (Fabiszewski 1983), one can infer, that the tolerance to heavy metals emitted by the smelter, may have got fixed, owing to the population plasticity of both the species. It may adapt the plants not only on physiological level, but may also concern processes significant for survival, like birth and mortality.

Biomass distribution

Observing of biomass, expressed in various form is, so to say, a traditional duty of investigators dealing with the early succession stages (compare, Symonides and Borowiecka 1985; Fabiszewski 1986; Symonides and Wierzchowska 1990; Falińska 1991). However, recently the researchers accept more and more the physiological criteria of individual plants and populations as good indices of rate and direction of old field early succession (Bazzaz 1996). In case of the presented results (Fig. 4), the biomass of rhizomes and aerial shoots differed in the investigated plots K, A, B, C, but did not show significant differences, except of the control surface, during the years 1991–1994. This is probably connected with the mentioned earlier monoculture on the investigated surface and the stressing influence of the smelter, keeping the status quo of the couch grass populations (A, B, C) during the whole period of investigations. During 1991–1994 on surface K progressing were phenomena typical for monocultures, consisting in regulation of population size through density-dependent processes, determined by crowding and size of individuals (Harper 1977; Weiner and Thomas 1986). At the beginning of the investigations (1991) the biomass, both of the above-ground and below-ground parts, is equal on all the four surfaces. Also the total length of rhizomes (per 1 m^2) differed only slightly on the particular surfaces and exceeded 24.5 m only in population B. In 1992 there was a striking drop of rhizome biomass only on plots situated near the smelter (A, B). An increase of shoot biomass was recorded during 1993–1994, above all in the control plot and in plot C. A less significant increase was observed in plots A and B. At that time there was also a slight increase in rhizome biomass in A and B. The length of rhizomes on the observed surfaces showed in consecutive years a small differentiation. An exception were here the plots C (1992) and B (1993), with rhizome lengths straying considerably from the mean, as a result of destruction of these underground parts by herbivores, probably voles.

Most similar to the behaviour of a wild population are the plots on the control point and the most distant from the copper

Fig. 4. Means ($\pm$ SE) of total dry weight of rhizome (shaded, $N = 4$), shoots (unshaded, $N = 4$) and total length values of rhizomes per m^2 ($\pm$ SE) (tops of bars, $N = 6$) from different populations of couch grass during four years of study.

smelter plot C and just they can be the exemplar for elaboration of a program of fighting against couch grass in particular in case of above-ground shoots. Their biomass underwent fluctuations with time, with a stable participation of biomass of the underground parts. The biomass, as well as the density are not very high, as on the investigated surfaces (fallow), forces increasing the vitality of couch grass, such as mowing or pasturage were not acting. However, most stable as a whole were the populations in points A and B, the growth of which was limited, above all because of a poorer development of aerial shoots, thus, set back most by the influence of the copper smelter. The height of specimens is there also the lowest, so that some of the stalks become simply dwarfish (Fig. 7). Both the mentioned populations do not show large differences in production of biomass of the underground parts and in the total length of rhizomes. Thus, the influence of the copper smelter on the total biomass of rhizomes and their length is not significant. The presented above results enable also the insight into the general potential of couch grass vegetative reproduction. The total length of rhizomes and their weight is situated within the range of quantities given by other authors (Neuteboom 1981, Pałys 1990). However, these values are far away from the records given by Pałys (l.c.). According to that author, the length of couch grass rhizomes per $1 m^2$ may reach 2752 cm, and the biomass 41.7 g/m 2 . Instead, according to Bojarczyk et al. (1979), on the surface of 1 ha of a weed-choked field, the dry matter of rhizomes is 0.97 tons, and its length – 747 km. According to Wehsarg (1961), from the surface of 1 ha of a weeded field 50–150 g of fresh rhizomes can be obtained. These amounts are stunningly high, though characteristic also for other plants intensely producing rhizomes. A similarly rich „underground biology” of rhizomes is observed also in *Tussilago farfara* (Namura-Ochalska 1993). However, the mentioned above plant penetrates deeper soil layers than couch grass, showing at the same time a lower potential of vegetative reproduction.

Formation of rhizome buds

The possibility of producing rhizome apical buds and dormant axillary buds on a large scale is a basic propriety of couch grass, connected with its reproductive potential. Particularly the correlative inhibition of buds and the predominating factor controlling all bud activity connected with apical dominance by the rhizome apex is known since long (Smith and Rogan 1980; McIntyre 1987; McIntyre and Cessna 1998). For a field ecologist investigating the demographic phenomena of couch grass and its reproduction the general knowledge on this matter will be enough. The investigations of number of axillary buds on surfaces covered by the described populations (K, A, B, C) (Fig. 5) yield an interesting material for discussion. The highest similarities between the populations, irrespective of year and investigation, occurred in K and C and A and B. It is interesting that populations situated near the smelter produce significantly more buds than populations remote from the emitter. With persisting, stable biomass of rhizomes in populations K and C, the production of buds remains also stable. Instead, the emphasised earlier (Fig. 4), slightly increasing biomass of rhizomes in A and B correlates with the considerable increase of total buds number. Because on surfaces A and B during years no change in length of rhizomes was recorded, therefore it is presumed that in the vicinities of the smelter the rhizomes have short internodes which produce more axillary buds. McIntyre and Cessna (1998) noticed that in natural conditions the excision of

Fig. 5. Mean numbers ($\pm$ SE) of rhizome buds of four populations of couch grass in 1991-1994, $N = 5$.

shoots may influence the elongation of rhizome growth and also the growth of axillary buds. In our case, because of lack of pasturage and mowing, the production of rhizomes and buds is independent of the fate of above ground shoots. It may be supposed, that for this production the local conditions were responsible, in this the stressing influence of soil including the toxic heavy metals. This view finds confirmation in the results of the former investigation. Young rhizomes of couch grass from populations growing near the smelter, cultivated in a glasshouse on uncontaminated soil, reacted strongly to the lack of heavy metals with inhibition of buds growth (Brej 1998). This phenomenon suggests, in concordance with the present results, the existence of tolerance processes against the contaminated soil. This experiment proves also that tolerant populations are not able to extend their area beyond the closest vicinity of the copper smelter.

Interpretation of life tables

The synthetic picture of population dynamics are the life tables. In spite of difficulties in constructing life tables for rhizomatous, clonal and polycarpic plants among which couch grass belongs, such trials are fruitful, giving the possibility for a versatile comparison of various populations. The life tables (Fig. 6) were made for the four investigated populations. The data presented in the tables are means obtained during four years of investigations (since late autumn 1991 to winter 1994). In the presented material characteristic is the similarity of population dynamics of K and C and A and B. Worthy of notice is here the presence, persistent soil seed bank, differentiated numerically in the particular populations, from which, however, the origin of seedlings is minimal. The seeds need no after-ripening period, thus the lack of germination ability must depend in the investigated area on external factors. As was already emphasised, in dry periods during autumn months, in couch grass growing in the area under discussion recorded was earing and seed production; however, seedlings occurred sporadically. This concerns all of the investigated populations. As opposed to most populations of known plants (compare: Symonides 1986) the seed bank does not play a greater role in the processes of maintenance of the couch grass population. Despite the discrete character of generative reproduction, in populations K and C there occurred an increase in number of seeds stored in the surface bank (Fig. 6). In the years of investigation, seed production was recorded sporadically in populations A and C. No seedlings were observed in population A. During previous investigations (Brej 1998) it was recorded that in points A and B couch grass produced a small number of seeds which, however, because of high soil contamination were not

able to germinate and to pass through further juvenile stages. The density of the investigated populations in respect of aerial shoots was of stable character. The density increases in the vegetation season in the group of K and C populations, but in „contaminated” populations A and B stable values are maintained during the whole year. Both the genetic and vegetative fecundity of aerial shoots differed in favour of populations K and C. As seen, the ecological conditions of occurrence of populations A and B affect unfavourably the density of tillers, seed production, i.e., the formation of genets, as well as, the production of buds by aerial shoots. The dissimilarity of habitat conditions in the vicinity of the smelter affects still more the development of axillary buds on rhizomes, which can be regarded as the state of vitality of the below ground parts of couch grass (Grime 1979; Grime et al. 1988). The fact that the number of produced buds is the highest in population C (nearest the smelter) and B, and next in C and K is striking. This shows the existence of a peculiar defence system of defence and developmental strategy in couch grass populations, which in conditions of ionic stress protect their existence by a considerable production of propagules. The latter are entirely ready for production of further underground parts, of which consecutive aerial shoots can also originate. Fortunately, these apparently expansive populations A and B do not threaten the surrounding agricultural areas. The populations A and B switch almost exclusively to the production of rhizomes at the cost of seed production (Reekie 1991). The clarity of results obtained by means of simple life tables induced to give up the projection matrix (Silvertown and Lovett Doust 1993).

Seasonal changes (phenology)

In ecological papers not much attention is usually given to the seasonal dynamics of plant populations (Harper 1977; Begon et al. 1996; Crawley 1997). Meanwhile the seasonal rhythm belongs to the especially important ecological processes (Falińska 1996) and allows to determine the general state of plant populations. This problem is particularly important in investigations of populations subjected to stresses, e.g., ionic (Fabiszewski 1983), salt (Salzman and Parker 1985), and other natural and anthropogenic stresses. The stressors' action may accelerate or retard the occurrence of the particular phenological phases. To become convinced of that, usually long-term observations are required, and therefore population ecologists do not frequently perform such investigations. The retardation of early developmental stages of couch grass in the vicinity of the smelter is presented in Fig. 7. The emerging of above ground shoots becomes visible already in the second half of March (population K). In April they can be observed in the

Fig. 6. Diagrammatic life tables for *Agropyron repens* populations (A, B, C, K). Mean results from four seasons (November 1991 – November 1994). Types of shoots according to Sagar and Mortimer (1976).

localised most remote from the smelter population C, but in the most contaminated population A not before the second half of April. From these observations shoots should be excluded, which, particularly during soft winters, remain active through the whole year and start an intense photosynthesis already in the latter part of March. Advanced shoots on control plots appear at the very beginning of May (Fig. 7), but their development near the smelter comes about with considerable delay, i.e., at the beginning of June. The mature state of populations situated remote from the smelter was observed in mid-May, whereas in point B usually at the beginning of June, and nearest the smelter

(point A) not before mid-July, eventually at the beginning of August. From these observations it results, that the later the developmental phase of the population, the greater the retardation of its developmental stages. The state of maturity of couch grass in the area contaminated by smelter emissions may be delayed even by more than two months. Therefore the rarely appearing generative stage of couch grass develops in the polluted population not before autumn. The retardation of phenological phases in population A creates, at least theoretically, possibilities for its easy expansion on other periods than in populations not resistant to contamination. Stressing conditions

Fig. 7. Phenology of couch grass population – early development (March – Sept.) and mean height of aerial shoots based on four years' observations. A, B, C, K – permanent plots as in Fig. 1; 1 – emergence of aerial shoots, 2 – advanced shoots (tillering and rhizome branching), 3 – mature shoots, 4 – mean height.

existing in the vicinity of the smelter shorten considerably the subsequent developmental stages of couch grass, acting like strong climatic factors, distinctly retarding, e.g., in the mountains, the phenological stages of plant development.

Pattern of tillering

The old field succession of couch grass in the vicinity of the smelter and its several years' observations in the field allowed for some generalisations on differentiation of growth forms. The well known data by Bell (1984, 1991) confirmed the existence of two major patterns of rhizome arrangement: near-hexagonal forms and linear forms. Both the forms are also reflected in the growth of aboveground shoots of couch grass. This is illustrated in Fig. 8, showing the typical growth „phalanx” in population A, and „querilla” in population K. The hexagonal growth, both in rhizomes and aerial shoots, is well suited to tillering space efficiency, whereas near linear growth is capable of rapid expansion into new areas. Together the two types of growth were even labelled as two different strategies: the phalanx strategy and the querilla strategy (Lovett Doust and Lovett Doust 1982; Harper 1988). They can be applied for various couch grass populations, characterised by type of growth depending on contamination size. The invasive populations of couch grass show as a rule the querilla strategy (populations K and C), as emphasised among others by Harper (1977, 1988), which, through loose distribution of rhizomes and leaves, secures a rapid radial spread (colonisation of open habitats). With age of population a denser packing and growth of lateral clones in couch grass may occur, but in general the competition from the side of other species prevents such a „switch” of the population. In our case, the change in growth took place in consequence of specific soil conditions in the vicinity of the copper smelter. Apart of toxic elements, the soil in the vicinity of the smelter is also enriched with nutritive compounds and, as is well known (Werner and Rioux 1977), couch grass is an extravagant consumer of nutrients. In the presented above results it was noticed that in the area near the smelter there was an increase in

Fig. 8. Schematic pattern of tillering in two couch grass populations. K – unpolluted control, A – polluted population, a – connection of loose tiller clusters, b – connection of dense tiller clusters.

production of rhizome axillary buds, caused, as it seems, by the direct action of the toxic environment and a better supply of nutrients. The increase in buds number is also connected with shortening of internodes in couch grass rhizomes growing near the smelter, and thereby with producing more tufty tillers. For specimens growing barely up to 50-70 cm of height, it may be easier in dense tufts to survive the severe conditions of ionic stress existing near the smelter. A part of the buds produced on underground rhizomes growing distinctly more radial (than in populations K and C), remains still in dormancy and, so to say, waits for proper conditions. Apparently the phalanx-type strategy, together with lateral growth, leading to a more compact above-ground structure, creates possibilities for an easier management with external conditions existing in close vicinity from the smelter. However, on the other hand, according to Harper (1988), the shortening of rhizome internodes and the slow tillering in this strategy increases indeed the integration of clones, but causes also that they do not react plastically to the patchy, external environment. However, one can imagine that couch grass clones near the smelter are so determined, that survival becomes most important. Hence, the allocation of resources progresses, above all, to increase the reproductive effort. Considering the high heterogeneity of the soil habitat containing heavy metals, the shorter internodes are perhaps also in some measure effective in „search” for proper, i.e., less toxic habitats in the local soil. In that respect investigations were not performed. The change of strategy in populations near the smelter does also not influence the disintegration of clones, which still remain connected. This may evidence the constant physiological dependence of ramets and also, that integrated clonal growth helps plants’ forage for resources (Silvertown and Lovett Doust 1993). The population structure of the phalanx type is, from the agricultural point of view, more difficult for eradication than querilla, mainly because of a higher number of produced buds and short internodes. The vegetative material from a tolerant population can be used for recultivation of areas rich in heavy metals. It is proper to emphasise, that the dichotomic character of the above discussed two strategies ought to be treated as an extreme division. Slade and Hutchings (1987) demonstrated that in one plant species, according to environmental factors, various forms of growth may be discerned. Instead, Callaghan (1988) noticed that both the growth forms can be produced by the same plant, which creates only different modules forming specimens of different strategy, even in the same ecological conditions. Hence, the change of couch grass strategy from querilla into phalanx is, in the described conditions, probably of phenotypic character, fixed only by the long time of stress factors’ acting (50 years of existence of the copper smelter).

LITERATURE CITED

BASKIN C.C., BASKIN J.M. 1998. Ecology of seed dormancy and germination in grasses. In: Population Biology of Grasses. Cheplick G.P. (ed.). Cambridge University Press, Cambridge, p. 30-83.
 BAZZAZ F.A. 1996. Plants in Changing Environment. Limiting physiological, population and community ecology. Cambridge University Press, Cambridge.
 BEGON M., HARPER J.L., TOWNSED C.R. 1996. Ecology. Individuals, Populations, Community. Blackwell Scientific Publications, Oxford.

BELL A.D. 1984. Dynamic morphology: a contribution to plant population ecology. In: Perspectives on Plant Population Ecology. Dirzo R., Sarukhán J. (eds.). Sinauer Ass. Inc., Sunderland, p. 48-65.
 BELL A.D. 1991. Plant Form: An Illustrated Guide to Flowering Plant Morphology. Oxford University Press, Oxford.
 BOJARCZYK M., MALICKI L., RESZEL R. 1979. Reakcje rozłogów perzu (*Agropyron repens* (L.) P.B.) na deszczowanie i źródnicowanie nawożenie fosforowe lucerny (*Medicago x varia* Martyn) uprawianej na rędzinie. (In Polish with English summary). Annales UMCS. Ser. E, 34: 1-6.
 BREJ T. 1983. Ecological investigations on some plants in the region of intensive influence of the Legnica copper smelter. Zesz. Nauk. Akad. Rol. we Wrocławiu. Roln. 40, 141: 23-43.
 BREJ T. 1998. Heavy metal tolerance in *Agropyron repens* (L.) P. Bauv. populations from the Legnica copper smelter area, Lower Silesia. Acta Soc. Bot. Polon. 67: 325-333.
 CALLAGHAN T.V. 1988. Physiological and demographic implications of modular construction in cold environments. In: Plant Population Ecology. Davy A. J. et al. (eds.), Blackwell Scientific Publication, Oxford, p. 111-135.
 COUSENS R., MORTIMER M. 1995. Dynamics of Weed Populations. University Press, Cambridge.
 CRAWLEY M.J., (ed.), 1997. Plant Ecology. Blackwell Scientific Publications, Oxford.
 FABISZEWSKI J. 1983. Reagowanie populacji na stresy jonowe. In: Bioindykacja skażeń przemysłowych i rolniczych. Fabiszewski J. (ed.), Ossolineum, Wrocław, p. 47-56.
 FABISZEWSKI J. 1986. Heavy metal tolerance of *Cardaminopsis halleri* (L.) Hayek populations in the Polish Tatra Mts. Acta Soc. Bot. Polon. 55: 421-428.
 FABISZEWSKI J., BREJ T., BIELECKI K. 1983. Plant indication examinations on environmental influence of copper smelter. Prace Wrocl. Tow. Nauk. 207, Ossolineum.
 FABISZEWSKI J., BREJ T., BIELECKI K. 1986. Plant reactions as indicators of air pollution in the vicinity of a copper smelter. Acta Soc. Bot. Pol. 56: 253-263.
 FALIŃSKA K. 1991. Plant Demography in Vegetation Succession. Kluwer Academic Publishers, Dordrecht.
 FALIŃSKA K. 1996. Ekologia Roślin. PWN, Warszawa.
 FALIŃSKA K., (ed.), 1998. Plant Population Biology. W. Szafer Institute of Botany Polish Academy of Sciences, Kraków.
 GRIME J.P. 1979. Plant Strategies and Vegetation Processes. John Wiley, Chichester.
 GRIME J.P., HODGSON J.G., HUNT R. 1988. Comparative Plant Ecology. Unwin Hyman, London.
 HARPER J.L. 1977. Population Biology of Plants. Academic Press, London.
 HARPER J.L. 1988. An apophysis of plant population biology. In: Plant Population Biology. Davy A. J. et al. (eds.), Blackwell Scientific Publication, Oxford, p. 435-452.
 HÅKANSSON S. 1967. Experiments with *Agropyron repens* (L.) Beauv. I. Development and growth, and the response to burial at different developmental stages. Annals of the Agricultural College of Sweden 33: 823-873.
 HÅKANSSON S. 1968. Experiments with *Agropyron repens* (L.) Beauv. II. Production from rhizome pieces of different sizes and from seeds. Ann. Agricultural College of Sweden 34: 3-29.
 HÅKANSSON S. 1982. Multiplication, growth and persistence of perennial weeds. In: Biology and Ecology of Weeds. Holzner W., Numata N. (eds.). Dr W. Junk Publ., The Hague, p. 123-135.
 HÅKANSSON S., WALLGREN B. 1976. *Agropyron repens* (L.) Beauv., *Holcus mollis* L. and *Agrostis gigantea* Roth as weeds – some properties. Swedish J. Agric. Res. 6: 109-12.
 HENDRY G.A.F., GRIME J.P., (eds.), 1993. Methods in Comparative Plant Ecology. A Laboratory Manual. Chapman and Hall, London.
 KLIMEŠ L. et al. 1997. Clonal plant architecture: a comparative analysis of form and function. In: The Ecology and Evolution of Clonal Plants. H. de Kroon, J. van Groenendall (eds.). Backhuys Publ., Leiden, p. 1-29.

- KRAUS E. 1912. Die gemeine Quecke (*Agropyrum repens* P.B.) Deutsche Landwirtschafts-Gesellschaft. Arbeit 220, Berlin, 152 pp.
- LOVETT DOUST L., LOVETT DOUST J. 1982. The battle strategies of plants. New Scientist 95: 81-84.
- MAJEK B.A., ERICKSON C., DUKE W. 1984. Tillage effects and environmental influences on quackgrass (*Agropyron repens*) rhizome growth. Weed Science 32: 376-381.
- MALICKI L., BERBEĆ C. 1986. Uptake of more important mineral components by common field weeds on loess soils. Acta Agrobot. 39: 129-141.
- MARSHALL E.J.P. 1990. Interference between sown grasses and growth of rhizome of *Elymus repens* (couch grass). Agriculture, Ecosystems and Environment 33: 11-22.
- MARSHALL Ch., PRICE E.A.C., (eds.), 1999. Clonal Plants in Environmental Heterogeneity – Space, Time and Scale. Plant Ecol. (Special Issue) 141: 1-206.
- McINTYRE G.I. 1965. Some effects of the nitrogen supply on the growth and development of *Agropyron repens* L. Beauv. Weed Res. 5: 1-12.
- McINTYRE G.I. 1987. Studies on the growth and development of *Agropyron repens*: interacting effects of humidity, calcium, and nitrogen on growth of the rhizome apex and lateral buds. Can. J. Bot. 65: 1427-1432.
- McINTYRE G.I., CESSNA A.J. 1998. Studies on the growth and development of the rhizome and lateral rhizome buds in *Elytrigia repens*: some effects on parent shoot excision. Can. J. Bot. 76: 769-776.
- MIREK Z. et al. 1995. Vascular Plants of Poland. A Checklist. Polish Academy of Sciences. W. Szafer Institute of Botany, Kraków.
- MOORE P.D., CHAPMAN S.B., (eds.), 1986. Methods in Plant Ecology. Blackwell Sci. Publ., Oxford.
- MORTIMER A.M. 1983. On weed demography. In: Recent Advances in Weed Research. Fletcher W.W. (ed.). Farnham Royal, Commonwealth Agricultural Bureau, p. 3-40.
- MORTIMER A.M. 1984. Population Ecology and Weed Science. In: Perspectives on Plant Population Ecology. Dirzo R., Sarukhán J. (eds.). Sinauer Ass. Inc., Sunderland, p. 363-388.
- NAMURA-OCHALSKA A. 1993. Expansion of *Tussilago farfara* in disturbed environments. Part I – III. Acta Soc. Bot. Pol. 62: 75-99.
- NEUTEBOOM J.H. 1981. Effect of different mowing regimes on the growth of four clones of couch (*Elytrigia repens* (L.) Desv.) in monocultures and mixtures with perennial ryegrass (*Lolium perenne*). Meded. Landbouwhogeschool Wageningen 81 (15): 1-26.
- PALMER J.H. 1958. Studies in the behaviour of the rhizome of *Agropyron repens* (L.) Beauv. I. The seasonal development and growth of the parent plant and rhizome. New Phytol. 57: 145-159.
- PALMER J.H., SAGAR G.R. 1963. *Agropyron repens* (L.) Beauv. Biological flora of the British Isles. J. Ecol. 51: 783-794.
- PAŁYS E. 1990. Studia nad odchwaszczeniem ziemniaka na rędzinie ze szczególnym uwzględnieniem perzu *Agropyron repens* (L.) P. B. Wydaw. AR w Lublinie – Seria Rozprawy Naukowe 125: 1-59.
- PAWŁOWSKI F., BOJARCZYK M. 1986. Występowanie organów wegetatywnego rozmnażania chwastów wieloletnich w niektórych glebach. (In Polish with English summary). Roczniki Nauk Roln. Ser. A, 106: 155-168.
- RADOSEVICH S.R., HOLT J.S. 1984. Weed Ecology. John Wiley and Sons, New York.
- REEKIE E.G. 1991. Cost of seed versus rhizome production in *Agropyron repens*. Can. J. Bot. 69: 2678-2683.
- REBELE F. et al. 1993. Heavy metal contamination of spontaneous vegetation and soil around the cooper smelter Legnica. Acta Soc. Bot. Pol. 62: 53-57.
- ROLA J. 1985. Zagrożenie upraw polowych przez *Agropyron repens* i efektywność metod jego zwalczania. Materiały 30. Sesji Nauk., IOR, Poznań. p. 115-130.
- ROLA J., ROLA H., KUCHARCZYK A. 1988. *Elymus repens* (L.) Gould = *Agropyron repens* (L.) P.B. – stan zachwaszczenia pól uprawnych i skuteczność metod jego zwalczania. Materiały Krajowego Sympozjum w Bielsku Białej. Wyd. IUNG, Puławy. p. 13-34.
- RYEL E.J. et al. 1996. Experimental studies on the competitive balance between two Central European roadside grasses with different growth form. Bot. Acta 109: 441-448.
- SAGAR G.R., MORTIMER A.M. 1976. An approach to the study of the population dynamics in plants with special reference to weeds. Appl. Biol. 1: 1-43.
- SALZMAN A.G., PARKER A. 1985. Neighbors ameliorate local salinity stress for a rhizomatous plant in a heterogeneous environment. Oecologia 65: 273-277.
- SILVERTOWN J.W., LOVETT DOUST J. 1993. Introduction to Plant Population Biology. Blackwell Scientific Publications, Oxford.
- SLADE A.J., HUTCHINGS M.J. 1987. The effects of nutrient availability on foraging in the clonal herb *Glechoma hederacea*. Jour. Ecol. 75: 95-112.
- SMITH D.L., ROGAN P.G. 1980. Correlative inhibition in the shoot of *Agropyron repens*. Ann. Bot. 46: 285-296.
- SYMONIDES E. 1986. Seed bank in old-field successional ecosystems. Ekologia Polska 34: 1-29.
- SYMONIDES E., BOROWIECKA M. 1985. Plant biomass structure in old-field successional ecosystems. Ekologia Polska 33: 81-102.
- SYMONIDES E., WIERZCHOWSKA U. 1990. Changes in the spatial pattern of vegetation structure and soil properties in early old-field succession. In: Spatial Processes in Plant Communities. Krahulec F. et al. (eds.) Academia, Praha, p. 201-213.
- TRIPATHI R.S., HARPER J.L. 1973. The comparative biology of *Agropyron repens* (L.) Beauv. and *A. caninum* (L.) Beauv. I. The growth of mixed populations established from tillers and from seeds. Jour. Ecol. 61: 353-368.
- WEHSARG O. 1961. Chwasty polne. (Translation from German). PWRiL, Warszawa.
- WEINER J., THOMAS S.C. 1986. Size variability and competition in plant monocultures. Oikos 47: 211-222.
- WERNER P.A., RIOUX R. 1977. The biology of Canadian weeds. 24. *Agropyron repens* (L.) Beauv. Can. J. Plant Sci. 57: 266-280.
- WESOŁOWSKI M. 1983. Zachwaszczenie niektórych typów gleb w makroregionie południowo-wschodnim i środkowym Polski. cz. I. Zachwaszczenie perzem. (In Polish with English summary). Roczn. Nauk Roln., Ser. A, 105: 123-134.
- WESTRA P.H., WYSE D.L. 1981. Growth and development of quackgrass (*Agropyron repens*) biotypes. Weed Science 29: 44-52.
- WILLIAMS E.D. 1970. Studies on the growth of seedlings of *Agropyron repens* (L.) Beauv. and *Agrostis gigantea* Roth. Weed Res. 10: 321-330.
- WILLIAMS E.D. 1971. Germination of seeds and emergence of seedlings of *Agropyron repens* (L.) Beauv. Weed Res. 11: 171-181.
- WILLIAMS E.D. 1973. Variation in growth of seedlings and clones of *Agropyron repens* (L.) Beauv. Weed Res. 13: 24-41.
- WILLIAMS E.D., ATTWOOD P. J. 1971. Seed production of *Agropyron repens* (L.) Beauv. in arable crops in England and Wales in 1969. Weed Res. 11: 22-33.
- ZHUKOVA L.A., ERMAKOVA I. M. 1985. Structure and dynamics of coenopopulations of some temperate grasses. In: The Population Structure of Vegetation. White J. (ed.). Dr. W. Junk Publishers, Dordrecht. p. 179-224.

BIOLOGIA POPULACJI PERZU *AGROPYRON REPENS*
W STREFIE ODDZIAŁYWANIA HUTY MIEDZI LEGNICA

STRESZCZENIE

Praca jest rozwinięciem problemów związanych z biologią populacji perzu, u których we wcześniejszych badaniach autorka stwierdziła utrwaloną tolerancję na niektóre metale ciężkie. Prezentowane obecnie wyniki pochodzą z czteroletnich badań terenowych, prowadzonych na czterech populacjach perzu, rosnących w różnej odległości od emitora skażeń. Pozostawione jako odłogi, monokultury perzu reagują specyficznie na 50-letnie oddziaływanie emisji huty. W badaniach populacyjnych znalazło to wyraz w istotnie zróżnicowanej, w odniesieniu do kontroli, produkcji biomasy części podziemnych (rozłogi) i nadziemnych, jak również w śmiertelności i narodzinach pędów nadziemnych. Biomasa pędów nadziemnych oraz wielkość osobników zmniejsza wyraźnie wpływ huty, który jednakże nie jest tak istotny dla produkcji biomasy części podziemnych i ogólnej długości rozłogów. Populacja znajdująca się najbliżej huty nie wykazuje też większych wahań sezonowych w procesie narodzin i śmiertelności pędów nadziemnych i podziemnych. Mechanizm tolerancji tej populacji, narażonej na ostre warunki stresowe, polega na wytworzeniu się stanu stabilności, w którym populacja nie ulega większym oscylacjom, produkując wyrównaną liczbę pędów nadziemnych w czasie sezonu wegetacyjnego, przy czym nie ulega również większym wahaniom śmiertelność tych pędów. Możliwość produkowania na wielką skalę rozłogowych pączków szczytowych i śpiących pączków bocznych jest podstawą potencjału reprodukcyjnego perzu, również w warunkach stresu jonowego. Bliskie sąsiedztwo huty stymuluje wytwarzanie pączków bocznych, skracając równocześnie długość międzywęźli rozłogów, przy niewielkim wzroście ich ogólnej biomasy. Na te właściwości nie mają jednak wpływu losy pędów nadziemnych, które z braku wypasu i koszenia nie stymulują wzrostu elongacyjnego rozłogów i pączków bocznych. Zróżnicowana dynamika czterech badanych populacji znalazła wyraz w odmiennych parametrach, które przedstawiają tabele przeżywalności. Pokazują one, że warunki ekologiczne populacji A i B działają niekorzystnie zarówno na zagęszczenie pędów nadziemnych, produkcję nasion, jak i tworzenie pokoleń generatywnych oraz na produkcję pączków nadziemnych. Natomiast liczba rozłogowych pączków bocznych jest największa w populacji położonej najbliżej huty (powierzchnia A), co raz jeszcze świadczy o swoistym systemie obronnym i strategii rozwoju populacji perzu w warunkach stresu jonowego. Te pozornie ekspansywne populacje A i B, ze względu na swe specyficzne wymagania ekologiczne, nie zagrażają okolicznym terenom rolniczym. Stan dojrzałości perzu, jak i inne fazy fenologiczne są opóźnione w obszarze skażonym emisjami huty nawet o ponad dwa miesiące. Opóźnienie faz fenologicznych populacji A stwarza – przynajmniej teoretyczne – możliwości jej łatwej ekspansji na przyległe tereny, w innych okresach niż populacji nieodpornych na skażenia. W wyniku działania nadmiaru związków toksycznych, na poletkach znajdujących się obok huty stwierdzono zmianę strategii wzrostu populacji perzu z *querilla* (zwiadowczej) na *phalanx* (falangową). Jest to kolejne dostosowanie omawianej rośliny do trudnych warunków miejscowych, gdyż wzrost populacji typu *phalanx*, zapewniający większe skupianie się roślin i wzrost lateralny klonów perzu, prowadzi do powstania struktury kępowej. Skupiona, kępowa struktura nadziemna stwarza roślinom możliwości łatwiejszego uporania się z ekstremalnymi warunkami panującymi w pobliżu huty. Zintegrowany wzrost klonalny umożliwia też pobieranie istotnych substancji pokarmowych, jak i unikanie pobierania związków toksycznych. Z rolniczego punktu widzenia, struktura populacji typu falangowego jest trudniejsza do zwalczania niż forma zwiadowcza, głównie z powodu liczniej produkowanych przez perz pączków przybyszowych i krótkich międzywęźli. Z drugiej jednak strony, materiał wegetatywny z tolerancyjnej populacji mógłby być łatwo wykorzystany do rekultywacji i remediacji terenów z nadmiernymi ilościami metali ciężkich. Znajomość klonalnej architektury perzu w warunkach lokalnych, ułatwia walkę z tym uciążliwym chwastem, zwłaszcza mechaniczną. Nawet krótkotrwałe ugorowanie zajętego przez *A. repens* obszaru rozwija silną strukturę klonalną (podziemną i nadziemną) populacji, utrudniając późniejszą walkę z perzem.

SŁOWA KLUCZOWE: *Agropyron repens*, dynamika populacji, narodziny, śmiertelność, tabele przeżywania, fenologia, wpływ metali ciężkich.

BIOLOGIA POPULACJI PERZU *AGROPYRON REPENS*
W STREFIE ODDZIAŁYWANIA HUTY MIEDZI LEGNICA

STRESZCZENIE

Praca jest rozwinięciem problemów związanych z biologią populacji perzu, u których we wcześniejszych badaniach autorka stwierdziła utrwaloną tolerancję na niektóre metale ciężkie. Prezentowane obecnie wyniki pochodzą z czteroletnich badań terenowych, prowadzonych na czterech populacjach perzu, rosnących w różnej odległości od emitora skażeń. Pozostawione jako odłogi, monokultury perzu reagują specyficznie na 50-letnie oddziaływanie emisji huty. W badaniach populacyjnych znalazło to wyraz w istotnie zróżnicowanej, w odniesieniu do kontroli, produkcji biomasy części podziemnych (rozłogi) i nadziemnych, jak również w śmiertelności i narodzinach pędów nadziemnych. Biomasa pędów nadziemnych oraz wielkość osobników zmniejsza wyraźnie wpływ huty, który jednakże nie jest tak istotny dla produkcji biomasy części podziemnych i ogólnej długości rozłogów. Populacja znajdująca się najbliżej huty nie wykazuje też większych wahań sezonowych w procesie narodzin i śmiertelności pędów nadziemnych i podziemnych. Mechanizm tolerancji tej populacji, narażonej na ostre warunki stresowe, polega na wytworzeniu się stanu stabilności, w którym populacja nie ulega większym oscylacjom, produkując wyrównaną liczbę pędów nadziemnych w czasie sezonu wegetacyjnego, przy czym nie ulega również większym wahaniom śmiertelność tych pędów. Możliwość produkowania na wielką skalę rozłogowych pączków szczytowych i śpiących pączków bocznych jest podstawą potencjału reprodukcyjnego perzu, również w warunkach stresu jonowego. Bliskie sąsiedztwo huty stymuluje wytwarzanie pączków bocznych, skracając równocześnie długość międzywęźli rozłogów, przy niewielkim wzroście ich ogólnej biomasy. Na te właściwości nie mają jednak wpływu losy pędów nadziemnych, które z braku wypasu i koszenia nie stymulują wzrostu elongacyjnego rozłogów i pączków bocznych. Zróżnicowana dynamika czterech badanych populacji znalazła wyraz w odmiennych parametrach, które przedstawiają tabele przeżywalności. Pokazują one, że warunki ekologiczne populacji A i B działają niekorzystnie zarówno na zagęszczenie pędów nadziemnych, produkcję nasion, jak i tworzenie pokoleń generatywnych oraz na produkcję pączków nadziemnych. Natomiast liczba rozłogowych pączków bocznych jest największa w populacji położonej najbliżej huty (powierzchnia A), co raz jeszcze świadczy o swoistym systemie obronnym i strategii rozwoju populacji perzu w warunkach stresu jonowego. Te pozornie ekspansywne populacje A i B, ze względu na swe specyficzne wymagania ekologiczne, nie zagrażają okolicznym terenom rolniczym. Stan dojrzałości perzu, jak i inne fazy fenologiczne są opóźnione w obszarze skażonym emisjami huty nawet o ponad dwa miesiące. Opóźnienie faz fenologicznych populacji A stwarza – przynajmniej teoretyczne – możliwości jej łatwej ekspansji na przyległe tereny, w innych okresach niż populacji nieodpornych na skażenia. W wyniku działania nadmiaru związków toksycznych, na poletkach znajdujących się obok huty stwierdzono zmianę strategii wzrostu populacji perzu z *querilla* (zwiadowczej) na *phalanx* (falangową). Jest to kolejne dostosowanie omawianej rośliny do trudnych warunków miejscowych, gdyż wzrost populacji typu *phalanx*, zapewniający większe skupianie się roślin i wzrost lateralny klonów perzu, prowadzi do powstania struktury kępowej. Skupiona, kępowa struktura nadziemna stwarza roślinom możliwości łatwiejszego uporania się z ekstremalnymi warunkami panującymi w pobliżu huty. Zintegrowany wzrost klonalny umożliwia też pobieranie istotnych substancji pokarmowych, jak i unikanie pobierania związków toksycznych. Z rolniczego punktu widzenia, struktura populacji typu falangowego jest trudniejsza do zwalczania niż forma zwiadowcza, głównie z powodu liczniej produkowanych przez perz pączków przybyszowych i krótkich międzywęźli. Z drugiej jednak strony, materiał wegetatywny z tolerancyjnej populacji mógłby być łatwo wykorzystany do rekultywacji i remediacji terenów z nadmiernymi ilościami metali ciężkich. Znajomość klonalnej architektury perzu w warunkach lokalnych, ułatwia walkę z tym uciążliwym chwastem, zwłaszcza mechaniczną. Nawet krótkotrwałe ugorowanie zajętego przez *A. repens* obszaru rozwija silną strukturę klonalną (podziemną i nadziemną) populacji, utrudniając późniejszą walkę z perzem.

SŁOWA KLUCZOWE: *Agropyron repens*, dynamika populacji, narodziny, śmiertelność, tabele przeżywania, fenologia, wpływ metali ciężkich.