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ESTIMATION OF ROOT AND SHOOT GROWTH OF SELECTED GRASS SPECIES ON THE BASIS OF SEEDLING CHARACTERIZATION

ABSTRACT

Our study was designed to describe possibilities to estimate above- and below ground biomass of selected grass species by means of seedling development. *Festuca arundinacea* Schreb., *Festuca rubra* L., *Lolium perenne* L., *Poa pratensis* L., *Koeleria macrantha* (Ledeb.) Schultes, *Deschampsia caespitosa* (L.) P.B. were used in our experiment. On the basis of observations and measurements, differences between species, cultivars and ecotypes were described. Significant and positive correlation was found between root:shoot ratio at seedling phase and at mature plants.

Key words: turf grass, root system, aboveground biomass

INTRODUCTION

Effective use of turf grass is strictly connected with good species and variety selection made on the basis of morphological and biological features as well as site requirements (Prończuk 1994). Good lawn is usually a mixture of different species and varieties therefore selection of mixture components is very important for lawn quality. And it is not easy not only due to different growth and development patterns of grass species and cultivars, but also different reaction to climatic and soil conditions (Rutkowska and Hempel 1986, Grabowski *et al.* 1999a). Although intensive turf re-

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search performed in USA, Europe etc. (some literature cited in Waddington *et al.* 1992, Sherman 2006) recently published articles focused on this topic are not numerous in Poland. Articles published so far were mostly connected with numerous traits observed on well developed turf surfaces. Traits as visual merit, uniformity, shoots density, turf color, leaf fineness were observed and described for range of species and varieties (Waddington *et al.* 1992, Prończuk 1993, Prończuk *et al.* 1997, Grabowski *et al.* 1999, Żurek *et al.* 2001, Jankowski *et al.* 2003, Prończuk and Żurek 2008). Some effort has been paid also on grass growth dynamics at initial stage of plant development (Harkot 1998, Harkot 2006) or reaction to different site conditions as: drought (Żurek 2004, 2006), shade (Prończuk *et al.* 2003), frequency of mowing (Stuczyńska and Jakubowski 1980), fertilization and organic matter (Rutkowska and Pawluśkiewicz 1996, Dziamski *et al.* 2007, Tołwińska 1975). Research on grass root system, which is very important in plant life, with its critical role in survival of stress conditions, is also rather limited (Tołwińska 1975, Harkot and Czarnecki 1998, Harkot 2006, Prończuk and Żurek 2008, Dziamski i wsp. 2008). Differences among plant species in root system growth are assumed to influence their ability to acquire resources (water, nutrients etc.) and, consequently, their competitive ability (Gross *et al.* 1992). Breeders, scientists and turf grass 'end-users' often search for good criterion for prediction of mature plant growth and development on the basis of seedling observation and selection. As seedling development undergoes successive stages (i.e. unimbibed seed, radicle and coleoptile emergence, seminal roots growth and elongation etc.) many of mentioned traits are highly heritable (Gibson, 2009). It is also possible that some of mentioned traits may be reflected during next stages of plant growth.

The aim of our study was to find relations between seedlings and mature plants of six turf grass species on the basis of below- and aboveground biomass yields.

MATERIALS AND METHODS

Following entries of six turf grass species were selected for our study: *Festuca arundinacea* Schreb. – varietes: Rahela, WOM -100 and Asterix*, Festuca rubra* L. – ecotypes: POLLBS-263, POLLBS-578 and POLLBS-393, *Lolium perenne* L. – varietes: Lisuna, Numan and Gator*, Poa pratensis* L.- varietes: Chałupy, Srzeszowicka and ecotype POLLBS-587*, Deschampsia caespitosa* (L.) P.B. – variety Brok and ecotype POLLBS-236, *Koeleria macrantha* (Ledeb.) Schultes – ecotype UKR 119. Entries were selected to cover wide range of grass species suitable for turf. Despite of varieties and breeding strains of well known high turf quality, ecotypes used were of previously confirmed turf potential (Schmidt, personal communication). *Deschampsia caespitosa* and *Koeleria macrantha* are currently very promising for turf purposes, but there is lack of available seed material, therefore in case of this species only few, currently accessible accessions were used.

Experiment was divided into two phases: seedling phase (emergence of 6 – 10 leaves) and mature plants phase (up to 2.5 years old or 945 days since seed sowing).

Seed was sown in March of 2006 in soil mixture of 1 part of compost soil, 1 part of peat and 1 part of sand. Soon after seed emergence, seedlings were transferred to small pots of volume 0.2 dm^3. Fifty pots per entry were further placed in unheated glass house (mean air temperature 15ºC, water added as necessary) until they reached phase of 6-10 leaves. Depending of species it took 35 to 40 days from seed sowing. From 15 seedlings per entry (5 plants per 3 replications) above-ground biomass (further referred as to shoots), was cut off, dried and weight. Below-ground biomass (further referred as to roots) from pots were washed in water and also dried and weight.

In mid July of 2006, eighteen plants from each entry were randomly selected and transferred to metal pots (5000 cm^3, 20 cm in diameter, with drainage hole at the bottom, filled with 6.0 kg of soil mixture, same as for seed emergence, one plant per one pot). For the rest of test duration plants were grown outside, frequently watered as necessary and hand mowed, with clippings collected, dried and weight. Pots were mown three times in 2007 and four times in 2008. Each year in April and July pots were fertilized (30.9 kg N, 16.7 kg P, 49.6 kg K and 5.3 kg Mg). Each year at the beginning (March), mid (July) and end (October) of growing season three pots per entry were randomly selected. Plants were cut off and roots were washed in water, dried and weight. For each from above mentioned terms, shoot dry weight were calculated as sum of all previous cuts and the current one.

Results were further analyzed with SAS® statistical package. Fisher test (HSD) was used to calculate LSD values.

Weather conditions (monthly mean air temperature and total rainfall) were analyzed according to data recorded by the automatic meteo station of Institute of Meteorology and Water Management, located close to experiment. Mean air temperatures were above normal values (1995 – 2006), from 3.3ºC (June – December 2006) to 1.4ºC (2007). Only few months (August 2006, July and September to November of 2007 and September 2008) were slightly colder than normal (ca. 0.1º - 1ºC). Although any water deficits during experiment were reduced with artificial watering, it should be noted that rainfall at 2006 and 2008 were below normal value, 18.6 mm and 12.9 mm, respectively. During 2007, high rainfall amounts were noted from January to March and from June to July, as contrary to rainfall deficits from April to May and from August to November.

RESULTS

Climatic conditions as well as genetic properties of tested entries were the major sources of variation for characters measured or calculated (Table 1). Significant effect of entries used in experiment was found for all traits. Shoot dry matter yields were slightly more dependent on identified sources of variation than root dry matter yields.

Table 1

Results of three-way ANOVA/MANOVA performed on results obtained in experiment for mature plants (error mean squares)

Components of variation	Total biomass of:		Root / shoot ratio
	Shoots	Roots	
Years (2007 - 2008)	1443.90***	1467.29***	0.003
Seasons (1-3)	394.50***	144.87	1.432***
Entries (15)	94.32***	193.15***	1.374***
Years × Seasons	1.66	65.19**	0.567
Years × Entries	31.59**	46.62	0.166
Seasons × Entries	11.30	11.48	0.101
Years × Seasons × Entries	8.92	20.70	0.192

*** - P = 99%, ** - P = 95%

Table 2

Shoots dry mass of tested turf grass varieties and ecotypes (in grams per pot)

Species., variety name or ecotype number	2006	2007			2008		
	July	March	July	October	March	July	October
DC BROK	0.35–ABC	3.11–C	10.94	7.96–B	14.07–B	12.92–D	13.64–C
DC POLLBS-236	0.40–AB	5.18–B	10.47	7.69–B	13.30–B	12.71–D	18.26–B
FA ASTERIX	0.36–AB	4.59–B	11.71	18.52–A	21.38–A	24.46–B	29.03–A
FA RAHELA	0.14–D	2.89–C	9.38	11.89–AB	12.27–BC	23.98–B	19.35–B
FA WOM-100	0.37–AB	5.85–B	10.47	19.66–A	29.08–A	30.99–A	35.04–A
FR POLLBS-263	0.16–D	7.89–A	10.12	8.37–B	12.30–BC	13.42–D	16.13–B
FR POLLBS-393	0.13–D	5.83–B	10.52	13.11–A	12.69–BC	18.72–BC	26.76–AB
FR POLLBS-578	0.15–D	8.93–A	13.43	10.97–B	13.49–B	15.89–CD	22.65–B
KM UKR 119	0.24–BCD	3.77–B	8.51	7.84–B	12.84–BC	19.36–BC	16.05–BC
LP GATOR	0.43–AB	4.16–B	14.13	7.74–B	8.51–C	21.43–B	18.52–B
LP LISUNA	0.42–AB	3.18–C	9.45	8.91–B	9.58–C	21.95–B	17.74–B
LP NUMAN	0.45–A	3.94–B	12.67	15.73–A	10.44–C	19.39–BC	21.24–B
PP CHAŁUPY	0.20–CD	3.74–BC	17.45	17.73–A	15.73–B	17.88–C	24.74–B
PP POLLBS-587	0.23–BCD	2.78–C	8.18	6.02–B	4.20–C	11.21–D	13.82–C
PP SKRZESZOWICKA	0.15–D	4.36–B	8.91	5.37–B	5.54–C	10.72–D	14.73–C
Variation coefficient (CV–%)	43	38	22	44	46	31	30
LSD (P=95%)	0.18	2.11	n.s.	7.73	8.62	6.01	9.52

Explanations: DC - *Deschampsia caespitosa*, FA - *Festuca arundinacea,* FR - *Festuca rubra*, KM - *Koeleria macrantha*, LP - *Lolium perenne*, KM - *Koeleria macrantha,* PP- *Poa pratensis.* A, B, C, …. – means with the same letters are not significantly different (P>95%)

Seedling stage

Growth parameters of tested grass species were already different at the seedling phase (Table2 and 3). The highest seedling shoot dry matter yield (0.35 – 0.45 g/pot) was noted for *Lolium perenne*, *Festuca arundinacea* (excl. Rahela)

and *Deschampsia cespitosa*. As contrary to above, only 0.13 – 0.16 g/pot was noted for *Festuca rubra*, *F. arundinacea* Rahela and *Poa pratensis* Skrzeszowicka. High variation level was noted also for seedling root system dry weight (Table3). Roots of highest dry matter weight (0.32-0.51 g per pot) were developed by *Lolium perenne, Deschampsia caespitosa* and *Poa pratensis* (excl. variety Chałupy). For *Koeleria macrantha* ecotype, variety Rahela of *Festuca arundinacea* and two ecotypes of *Festuca rubra* (POLLBS-578 and POLLBS-393) the lowest root system dry matter weights were noted (0.2 g per pot). For other entries values between 0.2 – 0.3 g per pot were noted.

Table 3

Root system dry mass of tested turf grass varieties and ecotypes (in grams per pot)

Species, variety name or ecotype number	2006		2007		2008		
	July	March	July	October	March	July	October
DC BROK	0.33–BC	3.33–C	6.12–C	2.89–D	4.53–C	5.62–D	4.73–F
DC POLLBS-236	0.32–BC	4.02–B	5.29–C	2.10–D	5.12–C	7.21–D	6.72–E
FA ASTERIX	0.30–BCDE	4.35–B	6.81–C	14.70–B	22.09–B	21.15–C	20.72–D
FA RAHELA	0.19–FG	5.36–B	5.27–C	17.63–B	23.28–B	22.75–B	21.36–D
FA WOM-100	0.22–DEFG	3.79–C	3.97–D	10.87–C	20.18–B	21.27–C	23.74–D
FR POLLBS-263	0.37–ABC	13.45–A	18.26–A	19.78–B	24.56–AB	25.79–B	42.20–B
FR POLLBS-393	0.20–EFG	12.25–A	14.61–AB	30.29–A	29.29–A	42.33–A	52.25–A
FR POLLBS-578	0.18–FG	12.17–A	19.66–A	27.09–A	24.90–AB	23.50–B	40.19–B
KM UKR 119	0.13–G	4.01–BC	4.72–CD	7.81–C	15.46–B	13.36–C	13.64–E
LP GATOR	0.46–AB	5.08–B	9.24–C	13.87–B	13.65–B	13.82–C	15.28–D
LP LISUNA	0.37–ABC	5.07–BC	9.55–B	12.77–BC	12.82–BC	13.38–C	10.59–E
LP NUMAN	0.32–BCD	6.27–B	6.77–C	9.19–C	9.97–C	15.28–C	20.83–D
PP CHAŁUPY	0.26–BCDE	3.12–C	18.21–A	18.22–B	38.13–A	23.54–B	29.20–C
PP POLLBS-587	0.51–A	4.52–B	7.38–C	9.07–C	16.61–B	14.83–C	22.22–D
PP SKRZESZOWICKA	0.39–AB	3.21–C	11.58–B	16.30–B	12.66–BC	13.34–C	17.82–D
Variation coefficient (CV-%)	35	59	54	55	50	48	59
LSD (P=95%)	0.12	1.26	5.24	7.25	12.57	10.11	9.11

Explanations: DC - *Deschampsia caespitosa*, FA - *Festuca arundinacea,* FR - *Festuca rubra*, KM - *Koeleria macrantha*, LP - *Lolium perenne*, KM - *Koeleria macrantha,* PP- *Poa pratensis.* A, B, C, …. – means with the same letters are not significantly different (P>95%)

Root systems of seedlings of *Poa pratensis* variety Skrzeszowicka, ecotype POLLBS-587 and *Festuca rubra* ecotype POLLBS-263 were found to be heavier than shoots more than twice (Table 4). For the rest of tested entries root:shoot ratios were close to or lower than 1.0. The lowest values of seedlings root:shoot ratio (0.5 – 0.7) were calculated for *Koleria macrantha*, *Festuca arundinacea* variety WOM 100 and *Lolium perenne* variety Numan.

Table 4

Root to shoot ratio of tested turf grass varieties and ecotypes

Species., variety name or ecotype number	2006	2007			2008		
	July	March	July	October	March	July	October
DC BROK	0.9–D	1.1–B	0.6–C	0.4–C	0.3–C	0.4–D	0.3–E
DC POLLBS-236	0.8–D	0.8–B	0.5–C	0.3–C	0.4–C	0.6–C	0.4–E
FA ASTERIX	0.8–D	0.9–B	0.6–C	0.8–BC	1.0–C	0.9–C	0.7–D
FA RAHELA	1.4–BCD	1.9–A	0.6–C	1.5–B	1.9–BC	0.9–C	1.1–CD
FA WOM-100	0.6–D	0.6–B	0.4–C	0.6–C	0.7–C	0.7–C	0.7–D
FR POLLBS-263	2.3–BC	1.7–A	1.8–A	2.4–A	2.0–B	1.9–AB	2.6–A
FR POLLBS-393	1.5–BC	2.1–A	1.4–B	2.3–A	2.3–B	2.3–A	1.9–B
FR POLLBS-578	1.2–CD	1.4–AB	1.5–AB	2.5–A	1.8–C	1.5–B	1.8–B
KM UKR 119	0.5–D	1.1–B	0.6–C	1.0–BC	1.2–C	0.7–C	0.8–D
LP GATOR	1.1–CD	1.2–AB	0.7–C	1.8–B	1.6–C	0.6–C	0.8–D
LP LISUNA	0.9–D	1.6–A	1.0–C	1.4–B	1.3–C	0.6–C	0.6–D
LP NUMAN	0.7–D	1.6–A	0.5–C	0.6–C	0.9–C	0.8–C	1.0–D
PP CHAŁUPY	1.3–BCD	0.8–B	1.0–C	1.0–BC	2.4–B	1.3–B	1.2–C
PP POLLBS-587	2.2–B	1.6–A	0.9–C	1.5–B	3.9–A	1.3–B	1.6–B
PP SKRZESZOWICKA	2.6–A	0.7–B	1.3–B	3.0–A	2.3–B	1.2–BC	1.2–C
Variation coeff. (CV - %)	51	36	48	63	59	51	56
LSD (P=95%)	0.80	0.75	0.33	1.11	1.05	0.36	0.53

Explanations: DC - *Deschampsia caespitosa*, FA - *Festuca arundinacea,* FR - *Festuca rubra*, KM - *Koeleria macrantha*, LP - *Lolium perenne*, KM - *Koeleria macrantha,* PP- *Poa pratensis.* A, B, C, …. – means with the same letters are not significantly different (P>95%)

Mature plants - first year

Differences between entries were also found during further growth and development. The highest shoot biomass after first year of observations was developed by *Festuca arundinacea* (average 10.6 g per pot, total from three seasons – 31.7 g). However, high shoot biomass was not followed by high root biomass. For *Festuca arundinacea* average root biomass was only 8.1 g per pot (total from three seasons – 24.3 g) and it was lower than for *Lolium perenne* (8.6 g and 25.9 g, respectively), *Poa pratensis* (10.2 g and 30.5 g, respectively), and *Festuca rubra* (18.6 g and 55.9 g, respectively). The lowest values of both shoot and root biomass were noted for *Deschampsia cespitosa* and *Koeleria macrantha*. Root:shoot ratios were also different for tested entries since the first year of observations. It was the highest during all seasons for only one entry – ecotype POLLBS-263 of *Festuca rubra* but also high during spring and autumn for next ecotype from mentioned species – POLLBS-393. Average root:shoot ratio was the highest for *Festuca rubra* (1.9) and also high for *Poa pratensis* and *Lolium perenne* (1.3 for both). The lowest average value of root:shoot ratio (0.5) were found for ecotype POLLBS-36 of *Deschampsia cespitosa* and variety WOM100 of *Festuca arundinacea*, which produced very high amount of shoot biomass (36.0 g per year).

Mature plants - second year

In the second year of experiment, higher differences between tested entries and species were observed. Like in the 2007, the highest shoot dry mass was developed by *Festuca arundinacea* (average – 25.2 g per pot, total from three seasons – 225.6 g). Variety WOM100 from mentioned species produced significantly the highest shoot biomass during all seasons, and variety Asterix at spring and autumn. Contrary to above, *Poa pratensis* varieties and ecotype produced the average lowest shoot yields (average 13.2 g, yearly total 118.6 g). Similar relations as year before were noted for root biomass. It was the highest for *Festuca rubra*, with ecotype POLLBS05-393 ranked the highest among all entries during all seasons. Total yearly produced root biomass by mentioned ecotype (123.9 g) was 8.3 times greater then the lowest root biomass, produced by *Deschampsia cespitosa* variety Brok (14.9 g). The same relation calculated for yearly shoot biomass was only 1.4. Considering root:shoot ratio, the highest values were noted also for *Festuca rubra* (species yearly average - 2.0)

Table 5.

Correlation coefficients between seedling traits and mature plants characteristics

Year	Season	Mature plants traits	Correlation coefficients for seedling trais:					
			Shoot, dry mass		Root, dry mass	Root:/shoot ratio		
2007	Spring	Root system, dry mass	-0.46		-0.19	0.30		
		Shoots, dry mass	-0.32		-0.28	0.14		
		Root:shoot ratio	-0.31		0.01	0.26		
	Summer	Root system, dry mass	-0.57		-0.04	0.48		
		Shoots, dry mass	0.13		-0.08	-0.24		
		Root:shoot ratio	-0.66	**	0.09	0.71	***	
	Autumn	Root system, dry mass	-0.67	**	-0.31	0.38		
		Shoots, dry mass	0.16		-0.45	-0.46		
		Root:shoot ratio	-0.68	**	0.12	0.75	***	
2008	Spring	Root system, dry mass	-0.62	**	-0.38	0.22		
		Shoots, dry mass	0.20		-0.53	-0.56		
		Root:shoot ratio	-0.62	**	0.33	0.75	***	
	Summer	Root system, dry mass	-0.58	**	-0.41	0.23		
		Shoots, dry mass	0.32		-0.41	-0.61	**	
		Root:shoot ratio	-0.77	***	-0.09	0.65	**	
	Autumn	Root system, dry mass	-0.65	**	-0.29	0.39		
		Shoots, dry mass	0.1		-0.47	-0.41		
		Root:shoot ratio	-0.72	***	0.01	0.69	***	
Average		Root system, dry mass	-0.68		-0.33	0.37		
		Shoots, dry mass	0,19	**	-0.51	-0.54	**	
		Root:shoot ratio	-0.76	***	0.13	0.79	***	

*** - P = 99%, ** - P = 95%

In case of *Festuca arundinacea, Poa pratensis, Deschampsia cespitosa* and *Koeleria macrantha* increase (ca. 50 – 97%) of root dry matter measured in spring of 2008 as compared to autumn of 2007 was found. Increase of root dry matter during autumn and winter was only minor for *Festuca rubra* and *Lolium perenne* (ca. 2%).

Shoot dry matter increases between October 2007 and March 2008 were from 63.7 – 74.7% for *Deschampsia caespitosa* and *Koeleria macrantha* but from 25.0 – 26.0% for both *Festuca* species. Reverse relation was found for *Poa pratensis* and *Lolium perenne*, where decrease of ca.12% was noted in mentioned period.

Relations between seedlings and mature plants

For seedling shoot dry mass and seedling root:shoot ratio significant correlation coefficients with mature plants traits were calculated for all seasons (excl. March 2007) (Table 5). The highest correlation coefficient was calculated for seedling root:shoot ratio and mature plants root:shoot ratio averaged across all seasons ($r=0.79$, $\alpha > 0.001$). Above relation is true only for all tested entries, however similar trends were found also for entries in particular species: *Festuca arundinacea, Lolium perenne, Poa pratensis* and *Festuca rubra* (Fig. 1).

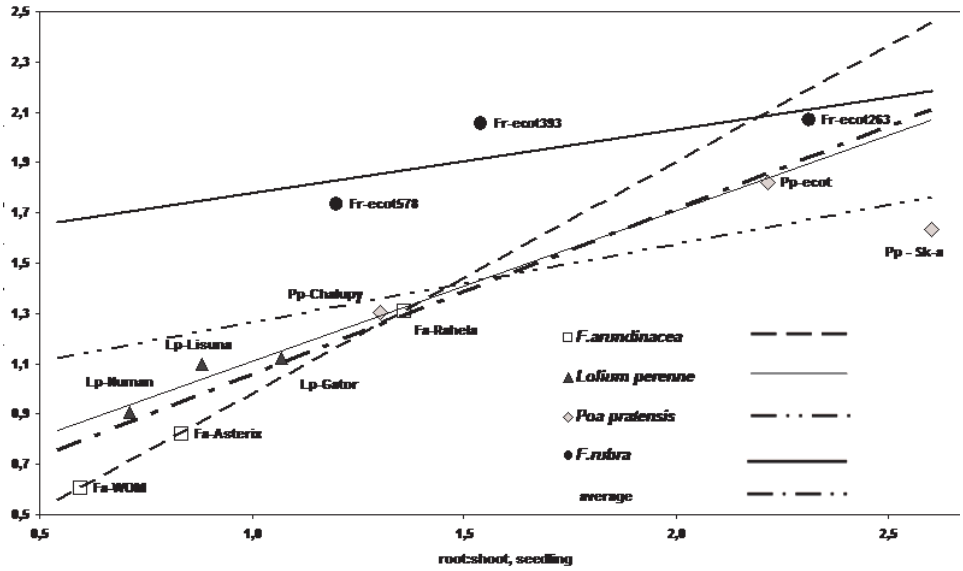

Fig. 1. Relation between root:shoot ratio at seedling stage and at mature plants (average from two years and 3 seasons per year)

Values of root:shoot rations observed at seedling phase are almost the same as for mature plants (averaged value) for *Festuca arundinacea* varieties. In case of two tested entries of *Poa pratensis* and all of *Deschampsia cespitosa,* seedling root:shoot values were higher as compared to mature plants values. For

Festuca rubra aforementioned relation was found for only one entry. For *Lolium perenne* varieties and *Koeleria macrantha* ecotype root:shoot ratios at seedling phase were lower than averaged values for mature plants.

DISCUSSION

Initial seedling growth rate and dimension of above- and belowground biomass were specific for species as well as varieties and ecotypes used. Similar high differentiation at initial stage of growth of turf grasses was described by others (Harkot 1998, Harkot 2006, Żurek 2004, Harkot and Czarnecki 1998). However, mentioned relations were the effect of different factors as time of sowing, frequency of mowing, natural and simulated drought, soil fertility or turf dry-out. We have made our conclusions on the basis of uniform soil, water and fertilization conditions. Generally, the extent of root system is correlated with above-ground growth (Gibson 2009). It is however, not quite sure at the seedling phase. On the basis of our results *Lolium perenne, Deschampsia cespitosa* and *Festuca arundinacea* shoots yielded much better then roots. Similar conclusions concerning seedling dimensions were given by Harkot and Czarnecki (1998) and Czarnecki and Harkot (2003). It has been concluded by Kittock and Pattersona (1962) that seedling size is the effect of seed size. Due to TSW data given for example by Falkowski (1982) it is questionable in case of *Deschampsia cespitosa*, species of very small seed size (TSW = 0.2 – 0.3 g), yielding seedlings of size comparable to *Lolium perenne* (TSW=1.3 – 2.5 g). Tufted hairgrass (*Deschampsia caespitosa)* is quite interesting species with large seedling and lowest root system with coincident high shoot growth. According to Żurek (1999) and Prończuk *et. al.* (2001) mentioned species is of great potential for extensive, shaded and sunny grass areas. Our results suggest that relatively small root system is able to regenerate during autumn and winter. Relatively good ability to regenerate could be the effect of natural, high chlorophyll contents in *Deschampsia* leaves (Falkowski 1982).

Root:shoot ratio is very important in defense against stress conditions, for example drought. *Festuca rubra,* due to it's ability to increase root:shoot ratio with decreasing water availability (reduction of above ground biomass with extensive root growth) is one from drought resistant species (Żurek, 2006, Dziamski *et al.* 2007).

CONCLUSIONS

1. Proportion of biomass allocated below and above ground varies among species, varieties or ecotypes at the seedling phase as well as 2.5 years old plants.

2. Specific genetic properties affect different biomass allocation. *Festuca rubra* and *Poa pratensis* produced relatively heavier root system as compared to shoots but for other species (*Festuca arundinacea, Lolium perenne, Deschampsia cespitosa, Koeleria macrantha*) mentioned relation was quite reverse.

3. Root : shoot ratio at seedling stage seems to be a good indicator of root:shoot values for mature plants.

4. Selection for high root:shoot values are mostly promising in *Poa pratensis* and *Festuca rubra* , where relatively high differences of root:shoot values at seedling stage among entries were noted.

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