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Root biomass accumulation in some varieties and hybrids of pea (*Pisum sativum* L.)

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ABSTRACT

Root biomass accumulation in spring and winter varieties and hybrids pea was recorded in field experiment in the Institute of Forage Crops, Pleven, Bulgaria (2011-2013). Spring (Shtambovyi and Pleven 4) and winter (Rosacrono and Pleven 10) varieties and their hybrids (Shtambovyi x Pleven 10 and Rosacrono x Pleven 4) (in first and second generation, F1 and F2) were investigated for fresh and dry root biomass accumulation at three phenological stages of plant development (budding, beginning of flowering and maturity). It was found that the tested varieties and hybrids pea accumulated different amount root biomass at the different stages of plant development. Pleven 10 (67.5 kg/da fresh and 11.28 kg/da dry root biomass) and Rosacrono x Pleven 4 (F1) (68.7 kg/da fresh and 14.8 kg/da dry root biomass) accumulated the greatest amount of root biomass at the budding stage. Winter variety Rosocrono accumulated the greatest amount of root biomass at the beginning of flowering (59.04 kg/da fresh and 16.20 kg/da dry root biomass). In this stage, hybrids Rosacrono x Pleven 4 formed significantly more root biomass in both generations, in F1 reached to 108.0 kg/da fresh and to 26.10 kg/da dry root biomass. At the maturity Pleven 10 formed 20.88 kg/da dry root biomass and the hybrid Shtambovyi x Pleven 10 (F1) - 24.96 kg/da, respectively. The genetical part in phenotypic expression for investigated traits in Pleven 10 x Shtambovyi was relative high and existed probability for selection of homozygous genotypes in F3 and F4 hybrid generations. The data for root biomass accumulation at different phenological stages could be used as parameters for characterization and differentiations of samples, hybrids and lines in this crop

Key words: dry root biomass, fresh root biomass, hybrids, root accummulation, Pisum sativum

Introduction

Legumes have well developed root system and through effective biological N2 fixation they derive a large proportion of N_2 and, in general, this is in excess of 70-80 % of their total N requirements (Larue & Patterson, 1981). Nitrogen in the roots of legumes is a continuous source of nitrogen in the ecosystem (Howieson et al., 1988).

Peas (*Pisum sativum* L.) are grown for forage and grain and are one of the main food legume crops. Under favourable conditions it can fix up to 150 kg N/ha and to accumulate in the soil 45-70 kg N/ha (Unkovich & Pate, 2000; Voisin et al., 2003; Clayton et al., 2004). Nitrogen in the roots constitutes 25-43% from the nitrogen in the whole plant, 70% from root mass in pea is located in the upper 15 cm of the soil profile (Evans et al., 2001; Williams et al., 2013).

Pea is with short vegetation season, root and bacterial biomass mineralized rapidly, and it is preferred in the crop rotations because of the positive effect on the next crop (Jensen, 1987; 1994; Beck et al., 1991; Schmidtke, 1996). Pea root biomass and biological nitrogen, accumulated there, contributed to increasing of soil fertility, manifesting a

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sustained action over 3-5 years after cultivation (Medvedev & Smetannikova, 1981; Sidorov, 1981; Tyutyunnikov & Fadeev, 1984; Ryabceva, 2009). According to Sidorova et al. (2010) pea can accumulate to 156 kg/da fresh and to 39.6 kg/da dry root biomass in the stage of beginning of flowering.

In the present work we had a purpose to study the quantity of root biomass, accumulated in spring and winter varieties and hybrids pea in three stages of plant development (budding, beginning of flowering, maturity).

Materials and Methods

A small-plot trial was carried out at the experimental field of the Institute of Forage Crops, Pleven (43.41°N, 24.61°E), Bulgaria (2011 – 2013). Parental forms of field pea (*Pisum sativum ssp. sativum*) – Shtambovyi and Pleven 4 (spring type), and *Pisum sativum ssp. arvense*) – Rosacrono and Pleven 10 (winter type) were used for crossing. Characteristics of genotypes tested are shown on Table 1.

These forms were crossed by hand in 2011. The parental forms (P1 and P2) and first and second generation (F1 and F2) were sown at scheme P1, P2, F2, F1 on a row spacing 70 cm and distance in a row 5 cm. Sowing by hand was applied with depth of 5 cm. Pea plants were grown according to the technology approved in the Institute. Soil monoliths (Beck et al., 1993) were taken at three phenological stages of plant development – budding (BBCH 55), beginning of flowering (BBCH 61) and maturity (BBCH 89) (BBCH-scale, 2001). There were 15 plants from each hybrid or parent fell into the monolith. Root system of plants was washed with tap water. Weight of fresh root biomass was measured (g/plant) after which dried at 60°C and weight of dry root biomass recorded (g/plant). Fresh root biomass (kg/da) and dry root biomass (kg/da) were calculated using the common methodology based on the sowing rate of pea plants (Sidorova et al., 2010).

Experimental data were statistically processed using software SPSS 10.0 for Windows 2000. Heritability coefficient in broad sense (H2) was determined using computer software GENES 2009.7.0 (Cruz, 2009).

Results and Discussion

Formation of biomass of the plant and its various organs is not only the result of the assimilation activity of photosynthetic tissues but also of the root system functioning (Novikova, 2012). Pea had a well-developed root system. The coefficient of correlation between weights of root and aboveground mass at the 6th true leaf stage of pea in field conditions reaches r = + 0.921.

Kwabiah et al. (2005) reported to 36.6 kg/da dry root biomass for growing season of pea. In our study the accumulation of root biomass in the different stages from the plant development was different. Differences were found for the forms of pea – winter and spring. At an earlier stage as budding one winter variety Pleven 10 (67.5 kg/da) accumulated more fresh root biomass as compared to Rosacrono (47.52 kg/da), and from the spring - Shtambovyi (65.4 kg/da) exceeded Pleven 4 (40.32 kg/da) (Table 2).

Smaller differences were found between the varieties for dry root biomass. Most dry root biomass accumulated Pleven 10 (11.28 kg/da).

For the hybrids the greatest amount of root biomass was formed by Rosacrono x Pleven 4 (F1) - 68.7 kg/da fresh and 14.8 kg/da dry root biomass, respectively.

At the beginning of flowering stage, from the spring varieties, Pleven 4 (51.84 kg/da) accumulated significantly more fresh root biomass as compared to Shtambovyi (39.6 kg/da), and from the winter ones, Rosocrono (59.04 kg/da) exceeded Pleven10 (29.52 kg/da). Smaller were the differences for the dry root biomass (Table 2).

Table 1. *Distinctive features of the investigated genotypes*

Traits	**Variety (genotype)**			
	Shtambovyi	**Pleven 10**	**Rosacrono**	**Pleven 4**
Vine type	short semi-erect	long-prostrate	long semi-erect	long semi-erect
Flower position	terminal (with fasciation – Fa, fac)	axial	terminal (with fasciation – fa, Fac)	axial
Stipule type	double	normal	double	normal
Leaf type	normal	normal	normal	normal
Flower color	white	purple	pink	white

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Table 2. *Accumulation of fresh and dry root biomass in varieties and hybrids pea*

Treatments	Fresh root biomass		Dry root biomass	
	g/plant	kg/da	g/plant	kg/da
		budding		
Shtambovyi	0.55±0.165	65.40	0.07±0.023	8.40
Pleven 10	0.56±0.041	67.50	0.09±0.023	11.28
Shtambovyi x Pleven 10 (F2)	0.27±0.072	32.70	0.05±0.022	5.70
Shtambovyi x Pleven 10 (F1)	0.33±0.070	39.60	0.05±0.025	6.40
SE (P=0.05)	0.07	8.86	0.01	1.25
Rosacrono	0.40±0.155	47.52	0.06±0.017	6.60
Pleven 4	0.34±0.148	40.32	0.06±0.027	7.20
Rosacrono x Pleven 4 (F2)	0.37±0.115	44.88	0.07±0.006	8.80
Rosacrono x Pleven 4 (F1)	0.57±0.043	68.70	0.12±0.012	14.80
SE (P=0.05)	0.05	6.29	0.01	1.87
min/max	0.27/0.57	32.7/68.7	0.05/0.12	5.7/14.8
		beginning of flowering		
Shtambovyi	0.33±0.104	39.60	0.08±1.3E-09	9.60
Pleven 10	0.25±0.009	29.52	0.11±0.017	13.20
Shtambovyi x Pleven 10 (F2)	0.38±0.077	45.12	0.08±0.025	9.12
Shtambovyi x Pleven 10 (F1)	0.39±0.129	46.32	0.13±0.029	15.12
SE (P=0.05)	0.03	3.83	0.01	1.44
Rosacrono	0.49±0.175	59.04	0.14±0.021	16.20
Pleven 4	0.43±0.133	51.84	0.09±0.016	10.56
Rosacrono x Pleven 4 (F2)	0.72±0.148	86.16	0.19±0.020	22.56
Rosacrono x Pleven 4 (F1)	0.90±0.425	108.00	0.22±0.076	26.10
SE (P=0.05)	0.10	12.9	0.02	3.44
min/max	0.25/0.9	29.52/108	0.08/0.22	9.12/26.1
		maturity		
Shtambovyi	0.10±0.007	12.00	0.09± 0.004	10.56
Pleven 10	0.17±0.092	20.64	0.17±0.093	20.88
Shtambovyi x Pleven 10 (F2)	0.32±0.231	38.64	0.21±0.141	24.96
Shtambovyi x Pleven 10 (F1)	0.30±0.172	35.76	0.20±0.102	24.24
SE (P=0.05)	0.05	6.30	0.02	3.32
Rosacrono	0.08±0.020	9.60	0.06±0.018	7.68
Pleven 4	0.07±0.031	8.64	0.07±0.031	8.64
Rosacrono x Pleven 4 (F2)	0.11±0.160	13.68	0.16±0.095	18.96
Rosacrono x Pleven 4 (F1)	0.09±0.011	11.04	0.09±0.005	10.32
SE (P=0.05)	0.01	1.09	0.02	2.57
min/max	0.07/0.32	8.64/38.64	0.06/0.21	7.68/24.96

Fresh root biomass in hybrids was greater than that of varieties and reached to 46.32 kg/da for Shtambovyi x Pleven 10 (F1), and 108.0 kg/da for Rosacrono x Pleven 4 (F1). Winter variety Rosacrono accumulated 16.2 kg/da dry root biomass at the beginning of flowering stage. Our results are in agreement with the findings of Sidorova et al. (2010) who reported accumulation of 16.8 kg/da dry root biomass at the stage of flowering of pea. Significant were the increases in dry root biomass for hybrids Rosacrono x Pleven 4 (F1 and F 2) as compared to varieties. Rosacrono x Pleven 4 (F1) formed the greatest amount of dry root biomass was (26.10 kg/da). Fresh and dry root biomass decreased with the progress of vegetation. According to Williams et al. (2013) root biomass in pea between stages beginning of flowering and maturity decreased. Thus, at the maturity stage for spring varieties Pleven 4 and Shtambovyi, fresh root biomass was 8.64 and 12.0 kg/da, respectively. The differences between winter varieties Rosocrono (9.60 kg/da) and Pleven 10 (20.64

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kg/da) were significant.

Hybrids Shtambovyi x Pleven 10 formed significant bigger amount of fresh root biomass as compared to varieties, both, in F1 and F2 (35.76 – 38.64 kg/da). The differences in dry root biomass accumulation were significant for the varieties Rosacrono and Pleven 4, and their hybrids. Rosacrono x Pleven 4 (F1 and F2) formed significantly more dry root biomass as compared to varieties and in F2 reached 18.96 kg/da.

The part from common variability conditioned from genetic differences was determined through using coefficient of heritability (H2). The inheritance is characterization of the relative part of the genetic differences and these which are result of the action of the environment in the phenotypic diversity. At change of genotype or the environment follow and variation of the assessment for inheritability.

In our study, a high coefficient of inheritance (H2) was found for the two groups varieties involved in the hybridization scheme (Figure 1A and 1B). Relatively lower it was for Rosacrono, Pleven 4 and their hybrids at the beginning of flowering stage. For Shtambovyi, Pleven 10 and their hybrids higher values of coefficient of inheritance were found as compared to Rosacrono and Pleven 4 at the earliest phenological stages (budding and beginning of flowering). Less difference was observed in this group for the inheritance of the traits studied for the three phenological stages. For the second group, where are Rosacrono and Pleven 4 varieties, at the budding stage the inheritance of dry root biomass trait exceeded dry root biomass trait by over 20%, and at the beginning of flowering stage by over 30%.

Table 3 shows the data for the difference in dry root biomass accumulation when comparing spring and winter varieties and their hybrids in different stages. At the budding stage no significant difference were found between varieties Shtambovyi and Rosacrono. Pleven 10 accumulated by 4.08 kg/da more dry root biomass as compared to Pleven 4. For the hybrids, Rosacrono x Pleven 4 accumulated by 3.10 kg/da more dry root biomass as compared to Shtambovyi x Pleven 10 for F2, and by 8.40 kg/da for F1. As a whole the differences in this stage are relatively small.At the beginning of flowering stage Rosacrono accumulated by 6.60 kg/da more dry root biomass than Shtambovyi, but less was the deference for the varieties Pleven 4 and Pleven 10 (2.64 kg/da). For hybrids, Rosacrono x Pleven 4 accumulated significantly more root biomass as compared to Shtambovyi x Pleven 10 (by 13.44 kg/da for F2 and by 10.98 kg/da for F1).

Pleven 4 accumulated by 12.24 kg/da more dry root biomass than Pleven 10 at the stage of maturity. In F2 Rosacrono x Pleven 4 accumulated by 6.00 kg/da more dry root biomass than Shtambovyi x Pleven 10, an opposite was the tendency in F1 (by 13.92 kg/da more root biomass for Shtambovyi x Pleven 10).

The quantitative traits determined the productiveness (in our study root biomass productivity) characterized with continuous variability due to the fact that the parent's varieties used in hybridization scheme contain alleles of different genes of given polygene series. As much as contrasting initial forms in their phenotype, the hybrids will combine more different alleles of genes from respective polygene series. In all hybrids, the variability of the studied traits were tested by CV%, characterizing the phenotypic diversity (Figure 2A and 2B). The variation was considered low, if CV was 10%, medium, if CV was between 10% and 30%, and high, if CV was higher than 30%, respectively.

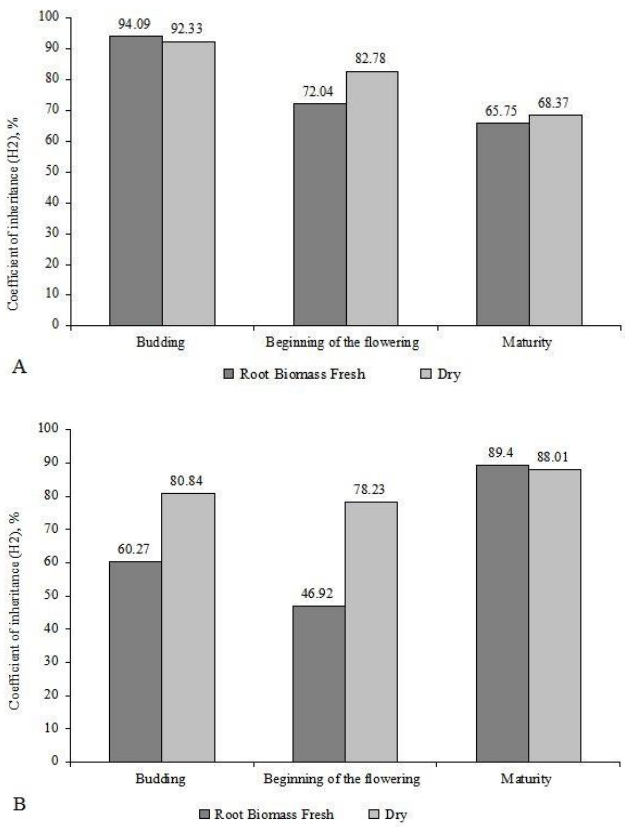

Figure 1. *Coefficient of inheritance in broad sense (H2), A – at Shtambovyi and Pleven 4 and their hybrids, B – at Rosacrono and Pleven 10 and their hybrids.*

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Table 3. *Dry root biomass in varieties and hybrids pea, spring/winter (+, - kg/da)*

Stages	Shtambovyi/ Rosacrono	Pleven 4/ Pleven 10	Shtambovyi x Pleven 10/ Rosacrono x Pleven 4 (F2)	Shtambovyi x Pleven 10/ Rosacrono x Pleven 4 (F1)
Budding	+ 1.80	- 4.08	- 3.10	- 8.40
Beginning of flowering	- 6.60	- 2.64	- 13.44	- 10.98
Maturity	+ 2.88	- 12.24	- 6.00	+ 13.92

Pea is with short growing period, accumulated significantly amount root biomass, mineralization of which occurs rapidly after harvest (Jensen, 1987; 1994; Beck et al., 1991; Schmidtke, 1996). Root biomass contains approximately 40% C, 18% of the root C for year falls in humus (Barber, 1979; Kwabiah et al., 2005), thus, pea with its root biomass contributes to maintaining and enhancing soil fertility. The data for root biomass accumulation at different stages could be used as parameters for characterization and differentiations of samples, hybrids and lines in this crop.

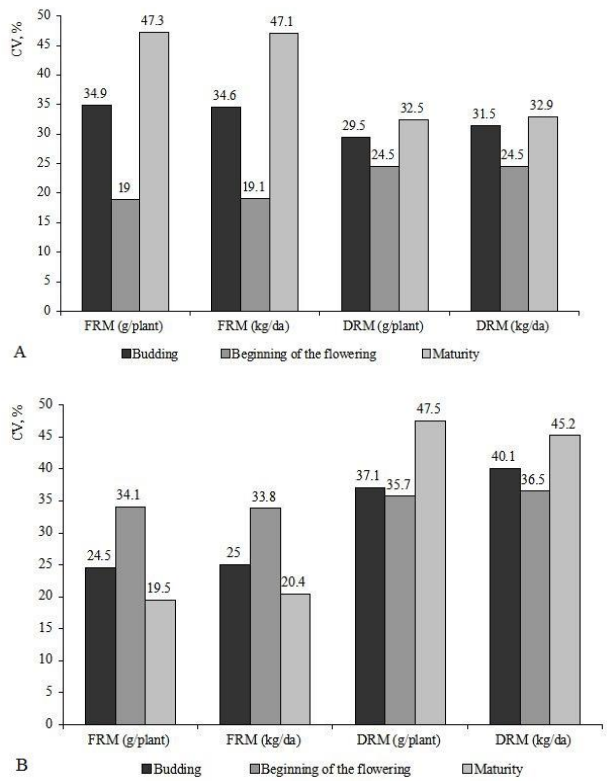

Figure 2. *Coefficient of variation (CV%) for root biomass accummulation, A - for Shtambovyi and Pleven 10 and their hybrids, B – for Rosacrono and Pleven 4 and their hybrids.*

Conclusion

Spring varieties pea Shtambovyi and Pleven 4, and winter ones Rosacrono and Pleven 10, and their hybrids accumulated different amount of root biomass in the different stages of plant development. At the budding stage Pleven 10 (67.5 kg/da fresh and 11.28 kg/da dry root biomass) and Rosacrono x Pleven 4 (F1) (68.7 kg/da fresh and 14.8 kg/da dry root biomass) accumulated the greatest amount of root biomass.

Winter variety Rosocrono accumulated great amount root biomass (59.04 kg/da fresh and 16.20 kg/da dry root biomass) at the beginning of flowering stage. In this stage, hybrids Rosacrono x Pleven 4 formed significantly more root biomass in both generations, in F1 reached to 108.0 kg/da fresh and to 26.10 kg/da dry root biomass.

At the maturity Pleven 10 formed 20.88 kg/da dry root biomass and the hybrid Shtambovyi x Pleven 10 (F1) - 24.96 kg/da, respectively.

At the beginning of flowering stage hybrids Rosacrono x Pleven 4 accumulated significant more root biomass as compared to Shtambovyi x Pleven 10 (by 13.44 kg/da for F2 and by 10.98 kg/da for F1) vs. maturity stage.

The genetical part in phenotypic expression for investigated traits in Pleven 10 x Shtambovyi was relative high and existed probability for selection of homozygous genotypes in F3 and F4 hybrid generations.

References

Barber SA.1979. Corn residue management and soil organic matter. Agron. J., 71: 625-627.

BBCH-scale. Growth Stages of Mono- and Dicotyledonous Plants. BBCH Monograph, 2. Edition. 2001. ed. Uwe Meier, Federal Biological Research Centre for Agriculture and Forestry, p: 138 (www.bba.de/veroeff/bbch/bbcheng)

Beck DP, Wery J, Saxena MC, Ayadi A. 1991. Dinitrogen fixation and nitrogen balance in cool-season food legumes. Agronomy Journal, 83: 334-341.

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Beck DP, Materon LA, Afandi F. 1993. Practical *Rhizobium*-Legume Technology Manual, ICARDA, Aleppo, Syria.

Clayton GW, Rice WA, Lupwayi NZ, Johnston AM, Lafond GR, Grant CA, Walley F. 2004. Inoculant formulation and fertilizer nitrogen effects on field pea: nodulation, N_2 fixation and nitrogen partitioning. Can. J. Plant Sci., 84:79–88.

Cruz CD. 2009. Programa Genes: Biometria. version 7.0. University of Federal Viçosa, Viçosa, Brazil.

Evans J, McNeill M, Unkovich MJ, Fettell NA, Heenan DP. 2001. Net nitrogen balances for cool-season grain legume crops and contributions to wheat nitrogen uptake: A review. Australian Journal of Experimental Agriculture, 41: 347–359.

Howieson J, Ewing M, D'Antuano M. 1988. Selection for acid tolerance in *Rhizobium meliloti*. Plant Soil, 105: 179-188.

Jensen ES. 1987. Seasonal patterns of growth and nitrogen fixation in field-grown pea. Plant and Soil, 101: 29-37.

Jensen ES. 1994. Availability of nitrogen in 15 N-labelled mature pea residues to subsequent crops in the field. Soil Biol. Biochem., 26, 465-472.

Kwabiah AB, Spaner D, Todd AG. 2005. Shoot-to-root rations and root biomass of cool-season feed crops in a boreal Podzolic soil in Newfoundland. Can. J. Soil Sci., 85: 369-376.

Larue TA, Patterson TG. 1981. How much nitrogen do legumes fix? Advances in Agronomy, 34: 15-38.

Medvedev PF, Smetannikova AI. 1981. The forage crops of European part of the USSR. L.: Kolos: 78-80. (in Russian).

Novikova NE. 2012. Problems of drought resistance of plants in aspect of selection of peas. Journal Zernobobovye I krupyanye kul'tury,, 1: 53-58.

Ryabceva MY. 2009. Some theoretical and experimental information on the specific organs nitrogen fixing root nodules, resulting from the symbiosis of pea *(Pisum sativum* L.) and bacteria рода *Rhizobium*. Agrarian Bulletin Urals, 6(60): 41-44. (in Russian).

Schmidtke K. 1996. Methodik zur Ermittlung der N-Flächenbilanz beim Anbau von Leguminosen. Mitteilungen der Gesellschaft für Pflanzenbauwissenschaften, 9: 43-44.

Sidorov MI. 1981. Fertility and tillage. Voronezh: 3-10. (in Russian).

Sidorova KK, Shumny VK, Vlasova EYu, Glyanenko MN, Mishchenko TM, Maystrenko GG. 2010. Genetics of symbiosis and breeding of a macrosymbiont for intense nitrogen fixation by the example of pea. Vestnic Vo GiS, 14(2): 357-374.

Tyutyunnikov AI, Fadeev VM. 1984. Improving the quality of feed protein. M.: Rosselhozizdat: 89-93. (in Russian).

Unkovich M, Pate JS. 2000. An appraisal of recent field mesurements of symbiotic N2 fixation by annual legumes. Field Crop Research, 65: 211-228.

Voisin AS, Salon CJ, Warembourg FR. 2003. Symbiotic N2 fixation activity in relation to C economy of *Pisum sativum* L. as a function of plant phenology. Journal of Experimental Botany, 54 (393): 2733-2744.

Williams JD, McCool DK, Reardon CL, Douglas JCL, Albrecht SL, Rickman RW. 2013. Root:shoot ratios and belowground biomass distribution for Pacific Northwest dryland crops. Journal of Soil and Water Conservation, 67(5): 349-360.

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