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Macroelement (N, P, K) Contents of *Arum euxinum* R. Mill During Vegetative and Generative Growth Phases

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Abstract: *Arum euxinum* R. Mill. is a geophytic plant belonging to Araceae. In this study nitrogen (N), phosphorus (P) and potassium (K) analysis were carried out during vegetative and generative growth periods. It has been found that above ground parts of plant usually have higher macroelement contents as compared to below ground parts during vegetative growth period. However, below ground parts have higher macroelement contents during generative growth phase due merely to top senescence.

Key words: *Arum euxinum* R. Mill., Araceae, macroelement content, vegetative growth period, generative growth period

INTRODUCTION

Geophytes are the plants in which the perennating bud is borne on a subterranean storage organ and their annual growth cycle usually includes a dormant period. The reserves in geophytic plants in their storage organ support leaf growth at the beginning of the growing season and, to a varying degree, also reproduction[1]. The redistribution of macroelements between above and below ground parts at the beginning and at the end of their growing season is highly important for the economical using of nutrients. Geophytic plants evade stress conditions such as shade, drought etc. by survival in below ground organs and they exhibit, hereby, some features of sun plants but also those of plants of shaded habitats[2]. In addition to this they have also interesting phenological properties such as flowering time (spring or autumn), the presence of protantherous and hysteranthous taxa etc.[3,4].

Spring ephemerals have a very short epigeous (period during which shoots are present aboveground) growth period of 40-60 days in spring. During the epigeous growth period, spring ephemerals accumulate mineral nutrients in their perennial organ and develop the buds for the next year's growth. Senescence of aboveground tissues is followed by belowground senescence and therefore the plant enters an apparent dormancy period at the end of spring. Dormancy is broken in autumn with bud and belowground growth that continues throughout the winter at a very slow pace, due to low soil temperatures and this growth period is called hypogeous growth, as it occurs underground[5].

A. euxinum R. Mill. is an endemic species and a spring ephemeral belonging to *Araceae*. It occurred on Euxine phytogeographic region. It has a vertical tuber. Petioles of leaves are often purplish. Lamina is oblong-hastate. Scape is (10.5-) 18-45 cm and always longer than petioles. Spathe purplish or greenish-purple outside, darker towards base, whitish with purple border inside, often cucullate. Tube is dark purple inside, lamina is ovate-lanceolate, acute or shortly acuminate. Sterile filaments reddish-purple or violet. Appendix is not stipitate and very slender[6]. *Arum* L. species widely used in medicine because they contain oxalic acid in whole plant and starch, mucilage and alkaloids (mainly coniin) in their fresh leaves and tubers[7] and they also contain neolignans[8].

Relative Somatic Costs (RSC) is a population measure of the relative difference of somatic investment between reproducing and non-reproducing individuals. RSC is frequently used to examine differences in vegetative growth rate associated with differences in reproductive investment[9]. RSC can be calculated, as the relative difference in somatic investment (I) between nonreproductive (In) plants and naturally reproducing plants (Is).

RSC is closely related to the Reproductive Effort (RE) because if the entire investment in reproduction (Ir) occurs at the expense of somatic growth (Is) then Ir+Is= In and in such a case RE= RSC. RSC may be

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estimated in different currencies such as nitrogen and phosphorus. RE is often defined as the proportion of total biomass allocated to seeds and other obvious reproductive structures and interpreted as representing the energy allocation of a plant to reproduction[10,11].

In this study the redistribution of some macroelements (N, P, K) between above and below ground parts and the correlations between plant and soil during vegetative and generative growth periods were examined. The contents of nitrogen, phosphorus and potassium seem to be more closely controlled than other nutrients, which could reflect the specific amounts needed for biochemical function[12].

MATERIALS AND METHODS

Study area: Plant samples were collected from Bafra (Kızılırmak valley; 36°0' E, 41°22' N), Merzifon (Tavsan Mountain; 40°53' E, 35°29' E) and Kastamonu (Küre Mountain; 41°59' N, 33°47' E) from Black Sea Region of Turkey (Fig. 1). The plants were collected from *Quercus cerris* L. var. *cerris* forest clearings. Bafra, Merzifon and Kastamonu populations were collected at 350, 950 and 1200 m, respectively.

Mean annual temperature and mean annual precipitation in Bafra are 14.3° C and 712 mm, respectively. Mean annual temperature in Merzifon and Kastamonu is 10.43 and 8.4°C, respectively. Mean annual precipitation in Merzifon and Kastamonu is 863 and 1666 mm, respectively. A xeric period was not observed in the study area[13].

Five plant individuals were used for macroelement analysis in each of vegetative and generative growth phases. In other words, sampling was repeated twice during vegetative and generative growth phases. Phenological observations were also recorded.

Method of chemical analysis: Plant samples were harvested during vegetative and generative growth phases and separated into above and below ground parts. After being washed in deionized water the plant parts were dried at 70°C to the constant weight and grounded in a Wiley mill and pass through a 20 mesh sieve. Nitrogen was determined by the micro Kjeldahl method with a Kjeltec 1030 Analyser (Tecator, Sweden) after digesting the samples in concentrated H_2SO_4 with a selenium catalyst. For P and K analysis plant specimens were wet ashed in concentrated HNO_3 and $HClO_4$ and P was determined by using Jenway spectrophotometer and K was determined by Petracourt PFP-7 flame photometer[14].

RSC was calculated, as the relative difference in somatic investment (I) between nonreproductive (In) plants and naturally reproducing plants (Is):

$$RSC = (In - Is)/In.$$

General linear models Procedure of SAS[15] was used to perform two-way analyses of variance. Statistical analysis were performed using MINITAB software package[16].

RESULTS

Phenological observations: Leaves are appeared at the end of February. The duration of vegetative growth period in *A. euxinum* is between at the end of February and at the first half of May. Flowering begins at the first half of May and continues up to the end of May. At the outset of June fruit ripening is occurred. The time interval for seed dispersion is between at the end of June to the middle of July. In Bafra (Kızılırmak valley) samples leaves are appeared one month early as compared to the other regions.

Plant analysis: Results shows that in vegetative growth period above ground parts have higher nutrient contents as compared to below ground parts (Table 1). However, P contents of above ground parts are lower than that of below ground parts during vegetative growth period on the contrary to general pattern in the samples collected from Bafra (Kızılırmak valley) population (Table 2). However, below ground parts have higher nutrient contents during generative growth phase inversely (Table 1 and 2).

The effective factors on dependent variable (N, P and K contents) were selected as plant parts (P; above and below ground), growth period (G; vegetative and generative) and location (L; Bafra, Merzifon, Kastamonu). P factor, G factor and L factors were accepted as two levels, two levels and three levels, respectively. In order to explain the dependent variable the following linear model was derived:

$$Y_{ijlk} = \mu + P_i + G_j + L_l + (PxG)_{ij} + (PxL)_{il} + (GxL)_{jl} + (PxGxL)_{ijl} + \varepsilon_{ijlk}$$

where, I=1, 2; l=1, 2, 3; j=1, 2 and k=1, 2, 3, 4, 5

For N concentration P factor was significant at 0.01 level. G and L factors were not statistically significant. However, there were a significant interaction between P and G factors. There were no significant interaction between P and L factors and P and G factors. General linear model for N concentration was significant at 0.01 significance level (Table 3).

For P concentration P, G and L factors were not statistically significant. However, there were a significant interaction between P and G factors. There were no

Table 1: Mean nutrient contents±standard error in below ground parts of *A. euxinum*

	N		P		K	
Locality	Vegetative	Generative	Vegetative	Generative	Vegetative	Generative
Bafra	1.458±0.04	1.796±0.32	0.216±0.11	0.234±0.19	0.132±0.10	0.152±0.09
Merzifon	1.142±0.22	1.232±0.46	0.196±0.14	0.222±0.10	0.096±0.06	0.139±0.05
Kastamonu	1.344±0.10	1.291±0.11	0.251±0.11	0.224±0.11	0.115±0.05	0.139±0.06

Table 2: Mean nutrient contents±standard error in above ground parts of *A. euxinum*

	N		P		K	
Locality	Vegetative	Generative	Vegetative	Generative	Vegetative	Generative
Bafra	2.660±0.03	2.665±0.80	0.184±0.08	0.265±0.12	0.316±0.05	0.507±0.07
Merzifon	3.046±0.30	2.195±0.06	0.355±0.17	0.194±0.16	0.432±0.25	0.236±0.17
Kastamonu	3.035±0.45	2.396±0.20	0.262±0.14	0.263±0.14	0.342±0.17	0.323±0.17

Table 3: Three-way variance analysis for N concentration

Source	df	Sum of Squares	Mean Squares	F	P
Model	15	28.499	1.90	12.646	0.00*
P	1	24.011	24.01	159.822	0.00*
G	1	0.414	0.414	2.756	0.104
L	2	0.539	0.270	1.794	0.178
P*G	1	1.499	1.499	9.978	0.003*
P*L	2	0.467	0.234	1.556	0.222
G*L	2	0.849	0.424	2.825	0.070**
P*G*L	2	0.302	0.151	1.004	0.375
Error	44	6.610	0.150		
Total	59	35.109			

* $p<0.01$, ** $p<0.10$, df: Degrees of freedom, R^2= 0.812, F: F-value, P: Probability, P: Plant part as above and below ground. G: Growth period as vegetative and generative, L: Location (Bafra, Merzifon, Kastamonu)

significant interaction between P, G and L factors. General linear model for P concentration was not significant at 0.01 significance level (Table 4).

For K concentration P factor was significant at 0.01 level. In other words, there were a significant difference between above and below ground K concentration. There were no significant difference between vegetative and generative growth period K contents. With respect to localities there were a significant difference at 0.10 significance level. The interaction between P and G factors was not significant. In addition to this, the interaction between three factors were also not significant. General linear model for N concentration was significant at 0.01 significance level (Table 3).

There were significant differences between above and below ground macroelement contents on the basis of N and K contents both vegetative and generative growth phases (Table 3 and 5).

The highest RSC values were found for Merzifon and Kastamonu populations in above ground parts of *A. euxinum* in terms of N contents. However, the highest RSC values were found for Kastamonu populations in below ground parts of *A. euxinum* in terms of N contents. The lowest RSC values were obtained for Bafra populations in above and below ground parts of *A. euxinum* in terms of P contents similar to N contents (Fig. 1 and 2). Only one significant difference was found between above and below ground parts of *A. euxinum* in terms of RSC (nitrogen). There were no significant differences between above and below ground parts of *A. euxinum* and localities in terms of nitrogen and phosphorus (Table 6).

Table 4: Three-way variance analysis for P concentration

Source	df	Sum of Squares	Mean Squares	F	P
Model	15	0.314	0.0209	1.437	0.173
P	1	0.0099	0.0099	0.685	0.412
G	1	0.0026	0.0026	0.185	0.669
L	2	0.0048	0.0024	0.168	0.846
P*G	1	0.0053	0.0053	0.364	0.549
P*L	2	0.0116	0.0058	0.399	0.673
G*L	2	0.0353	0.0176	1.214	0.307
P*G*L	2	0.0425	0.0212	1.459	0.244
Error	44	0.641	0.0145		
Total	59	0.955			

* $p<0.01$, ** $p<0.10$, df: Degrees of freedom, R^2= 0.329, F: F-value, P: Probability

Table 5: Three-way variance analysis for K concentration

Source	df	Sum of Squares	Mean Squares	F	P
Model	15	0.930	0.061	4.880	0.00*
P	1	0.631	0.631	49.700	0.00*
G	1	0.018	0.018	1.455	0.234
L	2	0.078	0.039	3.090	0.056**
P*G	1	0.0005	0.0005	0.46	0.831
P*L	2	0.040	0.020	1.584	0.217
G*L	2	0.036	0.018	1.456	0.244
P*G*L	2	0.048	0.024	1.908	0.161
Error	44	0.559	0.012		
Total	59	1.499			

* $p<0.01$, ** $p<0.10$, df: Degrees of freedom, R^2= 0.625, F: F-value, P: Probability

Table 6: The comparison of RSC values in *A. euxinum* by two-way ANOVA

Nutrient	Source	df	Sum of squares	Mean squares	F-value	Probability
N	Locality	2	0.066	0.033	6.38	0.267 NS
N	Plant part	1	0.1093	0.1093	20.97	0.040 *
N	Error	2	0.0104	0.0052	--	--
P	Locality	2	0.214	0.107	0.92	0.522 NS
P	Plant part	1	0.005	0.005	0.04	0.854 NS
P	Error	2	0.234	0.117	--	--

df: Degrees of freedom, ** $p<0.05$, NS: Non-significant

DISCUSSION

There were significant differences between above and below ground N and K contents. However, there were no significant differences between above and below ground P contents (Table 3-5). This is related to the phloem mobility of the nutrients. N, P and K can be ranked as K>N>P in respect to phloem mobility. In other words, P is a phloem-immobile nutrient as compared to K and N[17] There were no significant differences between localities in respect to N and P contents except for K contents. Mean annual rainfall was different in studied localities (750.2, 378.8 and 449.7 mm in Bafra, Merzifon and Kastamonu, respectively) and K is readily alleviated due to annual rainfall[18] and annual rainfall in Merzifon is comparatively lower than the other localities and alleviation in Merzifon should be rather low.

High N contents were found in above and belowground parts of *A. euxinum*. Above and belowground tissues of spring ephemerals are rich in nutrients especially nitrogen, compared with other forest herbs. Such high nutrient contents are required to sustain their high photosynthetic rates[5].

Negative RSC values were observed for Bafra and Merzifon populations. A greater investment of resources in reproduction at low nutrients may be possible if allocation to supporting structures is lower in unfertilized wild plants and they show a reduced allocation to stems[19]. Significant differences between above and below ground parts of *A. euxinum* in terms of RSC (nitrogen) which used for the explanation of RE in a different way were observed. The proportion of nitrogen allocated to reproductive structures is often higher than the proportion of other nutrients[11].

In vegetative growth period macroelement contents in above ground parts of *A. euxinum* were higher as compared to below ground parts. However, P contents of above ground parts are lower than that of below ground parts during vegetative growth period on the contrary to general pattern in the samples collected from Bafra (Kızılırmak valley) population (Table 3 and 4). The main reason of the high nutrient contents in above ground parts during vegetative growth period was due to the fast division of meristematic cells in above ground parts. High nitrogen contents in meristematic tissues were depend on the high protein content of that tissues[20,21]. However, in generative growth period below ground parts have higher nutrient contents as compared to above ground parts. Anderson and Eickmeier[22] stated according to vernal dam hypothesis forest herbs or herbs occur on forest clearings including geophytes temporarily sequester nutrients in deciduous forests prior to canopy closure and return them

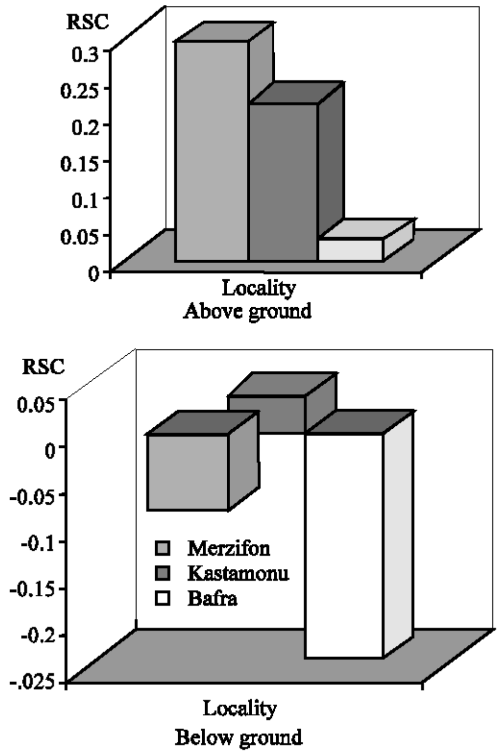

Fig. 1: RSC values in studied populations of *Arum euxinum* in terms of N concentrations

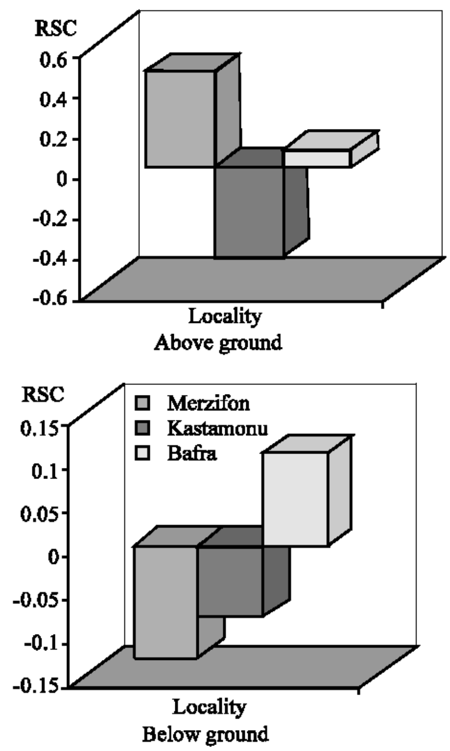

Fig. 2: RSC values in studied populations of *Arum euxinum* in terms of P concentrations

to the below ground tissues following senescence of above ground tissues. The studied taxa occur on usually forest clearings. The slow growth rate of aboveground parts of spring ephemerals during the hypogeous growth period could influence nutrient absorption rates, as nutrient needs are low. Low soil temperatures could also restrict nutrient uptake, although some uptake occurs very early on[5,22].

Similar results were also obtained in several other studies on geophytic plants[23-27]. This situation is known as top senescence[28]. In such plants the above ground parts senesce completely and new shoots appear at the beginning of the next season. The reserves in the vegetative storage organs allow a rapid growth during initial phase[29-31]. Senescence is an important process in the adaptation of higher plants to environmental conditions. This is a well controlled process and it is not a passive decay of a plant[4]. Senescence is allowed to the optimum usage of macroelements for a plant[32].

In addition to the top senescence monocotyledonous herbs have also adaptive advantages as compared to dicotyledonous herbs. For example, above ground parts of monocotyledonous herbs develop their leaves from a basal meristem. However, dicotyledonous herbs develop their leaves from an apical meristem. As a result of this meristematic tissues are at ground level in monocotyledonous herbs. This means that the benefit of a basal meristem at ground level, in terms of effective using of macroelements especially nitrogen, rapid transfer of nutrients between above and below ground parts, providing protection against damage through grazing, fire etc.[20].

Top senescence is an important strategy to the adaptation of geophytic plants to environmental conditions and main aim of this strategy is effective using of nutrients. The results of the present study can be evaluated in cultivation of *A. euxinum.* Future research should focus on top senescence in geophytic plants to a more precise explanation the nutrient patterns during vegetative and generative growth phases.

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