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ARTICLE

Studies on established *Acorus calamus* (L.) populations

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ABSTRACT The aim of this study was to investigate the sustainability, stress tolerance and growth parameters of an *ex situ Acorus calamus* population as well as the availability of the rhizome segments (ramets) for propagation. The main stress factors for semi aquatic plants, like *A. calamus* are the competition from dicot weeds and the severe dry conditions. We compared two experimental plots of different competition levels: low competition (moderate weeding) and high competition: without weeding. We noticed that there were differences between the competition levels only in terms of the life span of the leaves and the length of the shoots (aboveground parts). For the propagation we compared the ramets derived from the apical and lateral parts of the rhizomes as vegetative propagules. Plants derived from both types of rhizome parts showed dynamic development. We detected significantly higher leaf numbers in plants grown from lateral rhizome segments. The newly propagated plant population was kept free from weeds. However, its experimental plot was surrounded by a weedy lane. We found that the leaf number is correlated with the spatial arrangement of the individuals, namely the proximity of weeds decreased the leaf number of the plants in the periphery of the plot.
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KEY WORDS

Acorus calamus
stress tolerance
vegetative parameters
survival, competition

Characteristics of *Acorus calamus*

Acorus calamus (also known as sweet flag) belonging to the family of *Araceae* is a perennial plant, living in marshlands or other aquatic habitats, with 50-100 cm or even 1.5 m-long leaves (Farkas 1999). It has a horizontal underground rhizome, which is intensively branched, with a diameter of 1-3 cm and a length of 25-50 cm. The rhizome is articulated, rich in intercellular cavities. On the top of the rhizome there are the residues of the dead leaves, which are sickle-shaped. This is an important characteristic with which to distinguish *Acorus calamus* rhizomes from other rhizomes. The roots originate from the lower surface of the rhizome, in one or two rows.

The leaves are in two rows, they are sword-shaped with a red-pigmented base. Both surfaces of the leaves are a longitudinal rib, which divides the leaves into two asymmetric sections. The mesophyll is spongy, with a special aromatic odour.

Acorus calamus is native to Central-Asia, it came to Europe in the 16th century, and nowadays it can be found on the whole Northern hemisphere. In Central Europe it propagates only asexually, with the fragmentation of the rhizomes (Farkas 1999).

Since *A. calamus* is protected in Hungary, for the successful *ex situ* conservation we have to know as much as possible about the growth parameters, the successful survival and drought and competition tolerance.

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Materials and Methods

In the experimental area of the Botanical Garden of the University of Szeged, there was a formerly planted *ex situ* population of *Acorus calamus*. Originally it developed in monoculture, the individuals started to grow fast. Later on several competitors proliferated in the field. Although the competition level was high, there was a large calamus-density in the plot.

In order to detect the competition tolerance we separated two plots with different degrees of weed density (i.e.high and low competition levels). We counted the number of the leaves, and measured the length of the leaves and the shoots (the length of the longest leaf) using 50-50 ramets.

We selected ramets derived from the apical and lateral parts of the rhizomes (apical and lateral types) for the propagation of a novel population. The ramets were planted in the spring of 2008.

At planting we measured - the length of the rhizome of the ramets, the number of the shoots and leaves and the length of the leaves and that of the longest leaf (shoot length). We repeated the measurements of the aboveground characteristics in the autumn of 2008 and in the spring of 2009.

Statistical analyses of data were carried out using the STATISTICA 7.0 software. Since our results showed non-normal distribution, we used non-parametric ANOVA with

Table 1. Effect of the weed competition levels. Mean values of leaf number and shoot length per plant.

	Weed-competition level			
	High competition		Low competition	
	Leaf number	Shoot length (cm)	Leaf number	Shoot length (cm)
2008	-	-	2,07	35,7
2009	3,7	47,66	4,14	33,1

Table 2. Vegetative parameters of the transplanted population. Mean values of leaf number, shoot number and shoot length per plant.

	2008	2009
Shoot number	1,937	5,255
Leaf number	4,35	12,987
Shoot length (cm)	43,865	23,11

Wilcoxon's and Mann-Whitney post hoc tests. Data are given in mean ± standard deviation (SD).

Results

Effect of the weed competition

In autumn of 2008 we could not compare the vegetative characters of the two *A calamus* groups with different competition, because in the group of high competition the leaves already disappeared, indicating that the high weed competition decreases the life span of the leaves, *i.e.*, the length of the vegetation period. Individuals in the group of low weed competition had viable leaves, but numerous dead leaves were also seen.

In spring of 2009 both the leaf number and shoot length of the high competition level group were higher, than that in the low competition group. Probably the plants compensated for the shorter vegetation period with more and longer leaves (Table 1.)

Transplanted population

Vegetative parameters and survival

For planting we selected ramets with the same rhizome length. We registrated the data of the transplanted population in the autumn of 2008 and in the spring of 2009, so there were nearly one year (one vegetation period) between the two registrations.

The shoot number , leaf number and shoot length of the transplanted populations are summarized in the Table 2.

All the individuals of the transplanted population showed considerable development in one year. With the exception of the shoot length, all examined parameters were higher (Table 2.)

In 2008 all individuals survived, so we could state that the transplantation-time was ideal, and the used rhizome-fragments were suitable to survive. In spring of 2009 all ramets produced shoots except one, this means 98% survival rate. In that case we could not rule out the possibility of pest-predation.

There was a significant difference by the Mann-Whitney U-test in the leaf-number between the apical and lateral groups. (Fig. 1). The side-type rhizome, lateral rhizome

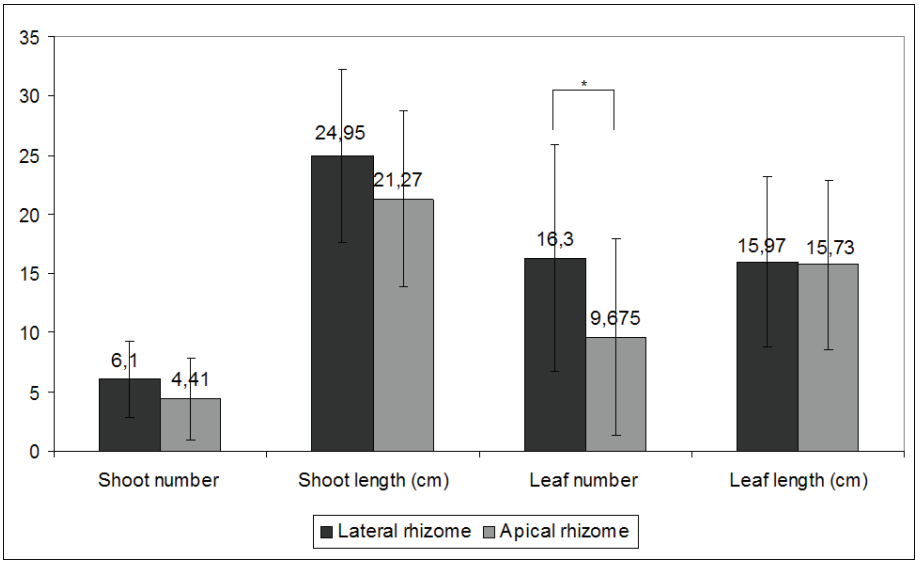

Figure 1. Comparison of the parameters of the transplanted group in spring 2009, by rhizome-type. Significant difference is marked with * at $p<0.05$.

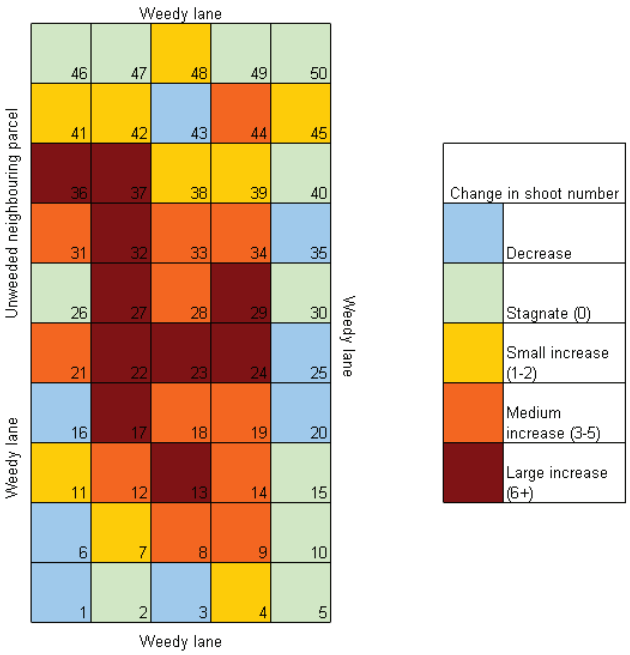

Figure 2. Shoot number changes by position in the experimental plot of competition-free population.

plants had substantially more leaves in the spring of 2009 than the end-type rhizome, apical rhinzome plants. On the other hand, there was no significant difference in the shoot- and leaf lengths and the shoot numbers between the two groups (Fig. 1).

When comparing the parameters of the individuals grown from apical and lateral rhizomes, it became clear that the lateral rhizome produced larger individuals, so for the vegetative propagation this type seems to be more suitable.

Effect of the weedy environment

On three sides of the experimental plot of the transplanted population there were weedy lanes, the plot itself was maintained without weeds. We detected that the plants near the weedy edge of the plot were smaller in the second experimental year. We compared the pattern of the shoot number between the two years. It was observed that at the edges where the individuals became closely contacted with weeds on one side, the shoot numbers decreased in 2009 as compared to the data of 2008. Individuals on the weed-free edge did not show the above-mentioned negative-edge-influence.

Inward to the centre of the plot the shoot numbers showed a rising tendency, in the middle of the non-competition area (where there were no competitors nearby) the shoot numbers increased dynamically, on one occasion we registered a nine-fold increment. Figure 2 shows the arrangement of the individuals in the plot. The numbers represent the individuals (Fig. 2).

Discussion

Our results show that *Acorus calamus* is able to tolerate the dry conditions. The weed competition has little influence on the growth characteristics of the older population, but the young plants tolerate the weeds at a lower degree, as seen on Figure 2.

For the vegetative propagation we recommend to use the side type rhizomes.

Variation of shoot numbers depends on the localisation in the experimental parcel in the case of the transplanted, competition-free group. On the edge of the parcel we noticed let-up or stagnancy in shoot numbers, while inward to the middle of the parcel, the shoot numbers showed remarkable growth.

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