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SURVIVAL AND AUTOTOMY RATES IN *CUCURBITA MOSCHATA* DUCHESNE (PUMPKIN) AFTER TRANSPLANTING

Ji-Young Hwang
Food Science and Technology Major /Dong-eui University, **KOREA**
hjy@deu.ac.kr

Man Kyu Huh*
Food Science and Technology Major /Dong-eui University, **KOREA**
mkhuh@deu.ac.kr

ABSTRACT

Cucurbita moschata Duchesne (pumpkin) is a species originating in either Central America or northern South America. Pumpkin is a multipurpose fruit and leaf vegetable. At the cotyledon or leaf stage when seedlings were approximately 1-10 cm, the young plants were transplanted outdoors. Survival and autotomy rates of pumpkin over time for the different treatments (pH, temperature, transplanting time levels, length of stems, and number of leaves) were analyzed at the end of the experiment. The pH difference between the soil of the greenhouse and the soil of the field decreased the survival rate of the transplanted plants. More autotomy events occurred at lower temperatures than at higher temperatures. When stem length was 1 - 3cm, there was almost no autotomy events. When there was only a cotyledon or a leaf, there was almost no occurrence of autotomy events. This species, *C. moschata* appears unable to change its morphology rapidly in response to the conditions where the seedlings develop. Autotomy of *C. moschata* may signal a limited potential for adaptation.

Keywords: Autotomy, *Cucurbita moschata*, pumpkin, transplanting.

INTRODUCTION

The family *Cucurbitaceae* L. is predominantly of tropical origin with a few members that have been able to adapt to temperate climates (Chavez et al., 2011). The genus Cucurbita consists of five cultivated species and 10 wild species, with perennials or annuals plants (Teppner, 2004). *Cucurbita moschata* Duchesne is a species originating in either Central America or northern South America (*Hui, 2006).* It includes cultivars known as squash or pumpkin. Pumpkin now occupies a prominent place among the vegetables owing to its high productivity, nutritive value, good storability, long period of availability and better transport potentialities (Hazra et al., 2007). Pumpkins have long been used for traditional medicine in many countries, such as China, Argentina, India, Mexico, Brazil, and Korea, since pumpkin flesh and seeds are rich not only in proteins, antioxidant vitamins, such as carotenoids and tocopherols (Stevenson et al., 2007), and minerals, but low in fat and calories. β-carotene reduces skin damage from the sun and acts as an anti-inflammatory agent (Kim et al., 2012). Preliminary investigations showed that a pumpkin-rich diet could reduce blood glucose, and the active polysaccharides from the pumpkin fruit could evidently increase the serum insulin levels, reduce the levels of blood glucose, improve glucose tolerance, and hence be developed as new antidiabetic agent (Caili et al., 2006; Hossain et al., 2018). The most frequently consumed *Cucurbita* species in Korea are *C. moschata* and *C. maxima*, whereas *C. pepo* consumption is relatively low (Kim et al., 2012).

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Transplanting is an economically and environmentally ideal alternative to seeding. Transplanting achieves what many are looking to accomplish: increase yields and quality, while decreasing costs, inputs and environmental impact.

Pumpkins are grown from seeds. In agriculture and gardening transplanting or replanting is the technique of moving a plant from one location to another. Transplanting reduces the need for general labor. Korea is a traditional farming society, but young people go out into the cities and the aging process is so rapid that the labor shortage in rural areas is very serious. Studies on the effect of environmental conditions on plants and microorganisms are a central issue in ecology, and they require an adequate experimental setup (Lazzaro et al., 2011). However, most of these studies are limited to surveys and comparisons of community structures or to laboratory-based incubations of extracted microbial consortia under different conditions (Bradford et al., 2010; Dimitriu et al., 2010). Greenhouse for corporate production containerized transplant production is the most common and successful transplant system used Korea. For the gardener growing from seed, transplants offer lots of flexibility in planning and growing crops. For example, pumpkin seeded indoors in April can be transplanted in late April or early May when conditions are suitable outdoors. However, after the transplantation of pumpkin seedlings, the autotomy phenomena were observed in many plants. Autotomy is a self-defence strategy of sacrificing a body part for survival. This phenomenon is usually widespread in the animal kingdom (e.g. gecko's tail) but was never reported in plants (Shtein et al., 2019).

The purpose of this study is to describe an autotomy phenomenon in the leaves of *Cucurbita moschata* after transplanting.

METHODOLOGY

Materials and Methods

For the experiment we selected one greenhouse at Dong-eui University in Busan, Korea and agricultural fields. The basic design in these experiments is similar in that seed was sourced from field sites, cleaned and cut tested to ensure high seed viability, germinated in a glasshouse, and then grown to the seedling stage before being transplanted. Twenty seeds per each experiment were sown into twenty pots in the greenhouse. At the cotyledon or leaf stage when seedlings were approximately 1-10 cm, the young plants were transplanted outdoors. The pH and temperature of the greenhouse were maintained at 5.6 and 22℃, respectively. The pH of soils is determined using Kelway PHD Soil PH Meter. Low pH experiments have adjusted by artificial acid rain. Alkali of the soil was controlled with $CaCO_3$. If the temperature is slightly higher than the greenhouse, the temperature of the soil is increased by covering with vinyl. Cold treatment mixed small pieces of ice with the soil. Survival and autotomy rate of pumpkin over time for the different treatments (pH, temperature, transplanting time levels, length of stems, and number of leaves) were analyized at the end of the experiment.

Statistical analyses

The samples were prepared in triplicate for each analysis and the mean value of measurements was obtained. The results were expressed as the mean ±SD. Data were analyzed using the SPSS version 21 (SPSS Inc, Chicago, IL) statistical software package (IBM Corp, 2012). The results were submitted to an ANOVA with an F test, and when relevant, the Greenhouse-Geisser (1959) was used to assess the change in a continuous outcome with two observations across time or within-subjects**.**

RESULTS

Both greenhouse and field experiments have limitations that likely account for the pH decline after transplanting (Table 1). The pH difference between the soil of the greenhouse and the soil of the field decreased the survival rates of the transplanted plants. Pumpkin did not grow well as its basicity was strong. In addition, autotomy was more common when they were basic.

Table 1. Survival and autotomy rate of pumpkin for pH levels between a greenhouse and an agriculture field after transplanting

Difference of pH	Survival (%)	Autotomy (%)
-1.0	53.7±4.16	30.7±4.93
-0.75	70.7±2.52	28.3±2.52
-0.50	91.3±3.51	16.7±2.08
-0.25	94.0±3.61	3.67±1.15
0	99.0±1.00	2.33±0.58
0.25	91.7±1.53	5.67±1.15
0.50	80.0±2.65	30.7±2.53
0.75	62.3±2.08	38.3±0.58
1.0	44.3±3.06	46.7±2.08

When the temperature at fields was slightly higher than the greenhouse, the survival rate was maintained at 100% (Table 2). On the other hand, when the soil temperature of the field was lower than that of the greenhouse, the survival rate was drastically lowered. More autotomy events occurred at lower temperatures than at higher temperatures. Therefore, low temperature after transplantation may cause stress to plants.

Table 2. Survival and autotomy rate of pumpkin for temperature levels between a greenhouse and an agriculture field after transplanting

Difference of temperature	Survival (%)	Autotomy (%)
-4.0	0.67±1.15	86.7±14.00
-3.0	54.0±8.54	65.3±5.03
-2.0	82.3±5.13	29.7±11.10
-1.0	95.7±2.08	4.67±1.53
0	100.0±0.00	0.33±0.58
1.0	100.0±0.00	3.33±1.53
2.0	100.0±0.00	7.67±2.08
3.0	100.0±0.00	13.3±1.53
4.0	98.3±1.53	17.7±2.52

Survival and autotomy rates of transplanting pumpkin at the length of stems were evaluated (Fig. 1). The length of the stem from the roots to the first leaf was not an important factor when transplanted. When stem length was 1~3cm, there was almost no autotomy events.

When the stem was long, some of the autotomy events occurred. Overall, stem length was not significantly different between survival and autotomy rates (p>0.05).

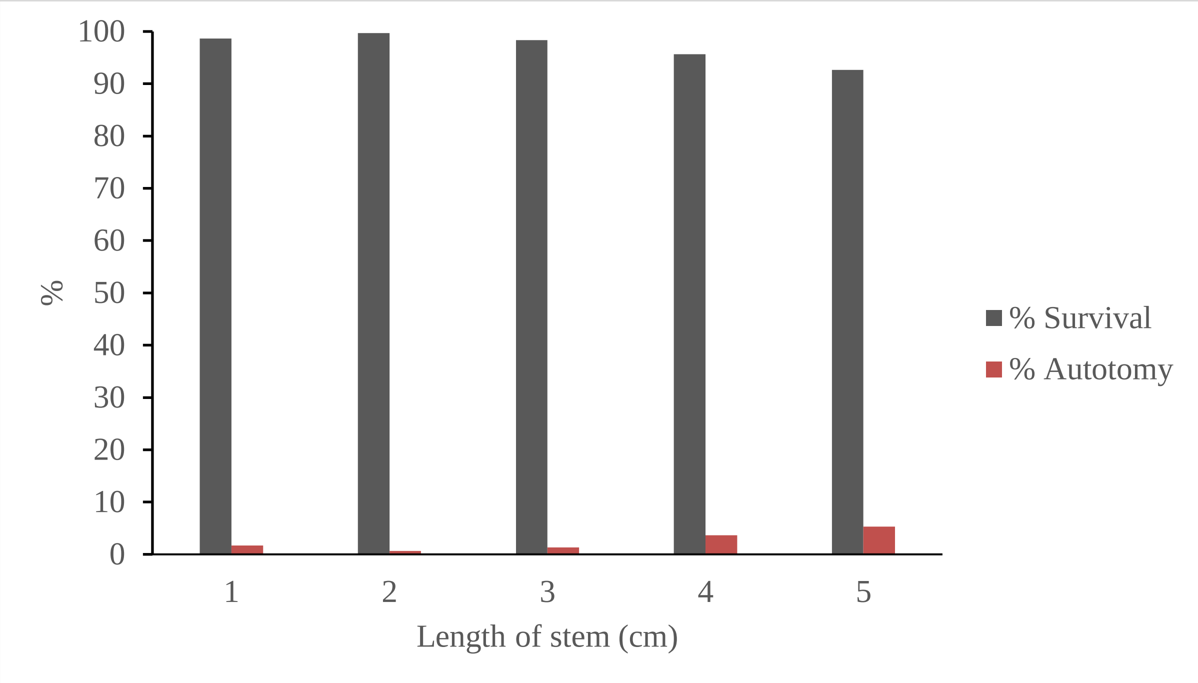

Figure 1. Survival and autotomy rate of pumpkin for length of stems after transplanting.

Survival and autotomy rates of transplanting pumpkin at the number of leaves were evaluated (Fig. 2). Overall, the length of the stem gradually increased as the number of leaves increased. When there was only a cotyledon or a leaf, there was almost no occurrence of autotomy events. As the number of leaves increased, the survival rate increased. On the other hand, the phenomenon of autotomy occurred more frequently. Although number of leaves are large, many autotomy events occurs. however, number of leaves was not significantly different between survival and autotomy rates (p>0.05).

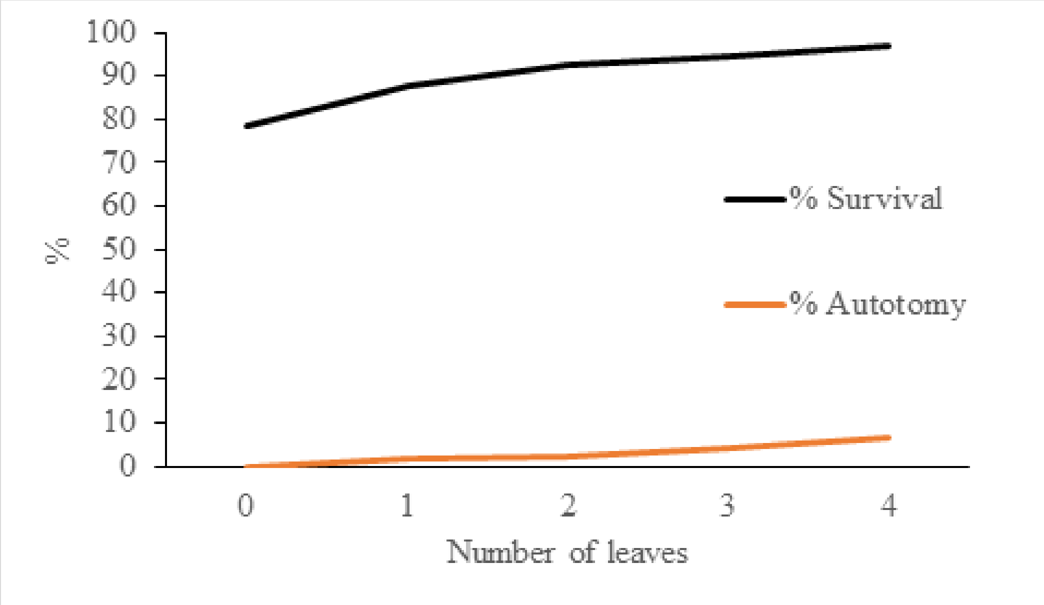

Figure 2. Survival and autotomy rate of pumpkin for number of leaves time after transplanting. 0: It is a young stage without a leaf (they have only two cotyledons). 1: The plants have two cotyledons and one leaf.

Survival and autotomy rate of pumpkin over time for the different treatments at the end of the experiment (Fig. 3). The stronger the sunlight, the better the survival and autotomy rates after transplantation. Transplantation at the end of the day had a high survival rate and low autotomy. There was not significantly different between survival rate and transplanting times ($p>0.05$). There was significantly different between autotomy rate and transplanting times ($p<0.05$).

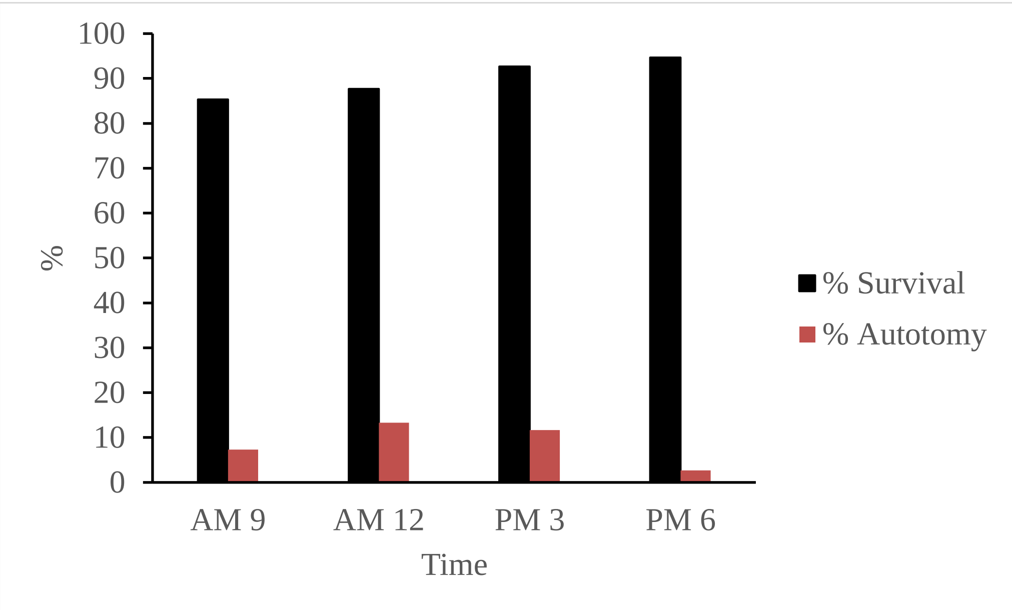

Figure 3. Survival and autotomy rate of pumpkin for transplanting time after transplanting.

DISCUSSION

Local adaptation can be defined in terms of the difference in fitness of populations on their home sites versus their fitness when transplanted to other sites (Blanquart et al., 2013), or the more stringent condition where the home site population is superior to the average fitness of other populations transplanted to the same site (Kawecki & Ebert, 2004). While some leaf loss is normal, there may be many reasons for a plant losing leaves. Shock from transplanting is probably the number one reason for leaf loss in plants. Shock is most often caused by a sudden change in conditions, such as when a houseplant has been enjoying outdoor conditions and is then brought indoors as cold weather approaches. Fluctuations in temperature, light, and moisture can have an adverse effect on plants, especially as they are transitioning from one environment to another-often resulting in the loss of foliage. In this study, temperatures can greatly affect plants (Table 2). Many plants will drop their leaves as a result of overly wet or dry conditions. For example, overwatering commonly results in leaf yellowing and the dropping of foliage. Dry, compacted soil can have the same outcome, as roots become restricted. To conserve water in dry conditions, plants will oftentimes shed their foliage. Stein et al. (2019) reportrd that leaf fracture in *Oxalisis* facilitated by an amplification of the far-field stress in the vicinity of local, but abrupt, geometrical modification in the form of a notch. They presented an autotomy-like defence mechanism which involves the sacrifice of vital organs in order to prevent the uprooting of the whole plant. Extensive variation in fractional resorption of mineral elements from plant leaves is still not fully understood. Species leaf fall phenology and leaf chemistry modify the timing and quantities of plant nutrient losses, and that more diverse forest stands supporting a spectrum of species with different phenologies and leaf types produce litter with more variable chemical characteristics than monotypic stands (Niinemets & Tamm, 2005).

This species, *C. moschata* appears unable to change its morphology rapidly in response to the conditions where the seedlings develop. Low levels of local adaptation can also occur in plants that show inherently high levels of plasticity, such as in the widespread weedy European species, *Buddleja davidii* (Ebeling et al., 2011). Autotomy of *C. moschata* may signal a limited potential for adaptation.

The rice fields used in this experiment was not good for plant growth. Thus it may have a characteristic that it may be prone to autotomy. However, we concluded that pumpkin was more susceptible to autotomy when pepper, tomato, and eggplant were planted in the same soil. In Korea, pumpkins are not mainly paddy fields, but they are planted on the hills of fields and fields.

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