Resource allocation to prey capture tissue in the aquatic carnivorous plant Utricularia vulgaris in northwestern Montana waters

Susan J. Trull
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Resource Allocation to Prey Capture Tissue in the
Aquatic Carnivorous Plant, Utricularia vulgaris,
in Northwestern Montana Waters

By

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B.A., Carleton College, 1982

Presented in partial fulfillment of the requirements for the degree of
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Approved by:

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June 6, 1988
Utricularia vulgaris L. plants were collected in northwestern Montana, from sites assumed to differ in dissolved inorganic nutrient availability. Plants were found to vary in their extent of prey capture tissue (bladders). To test the hypothesis that waters of low nutrient availabilities induce greater development of prey capture tissue than do waters of higher nutrient availabilities, U. vulgaris plants were raised under controlled laboratory conditions.

A common garden experiment was conducted, and U. vulgaris plants were found to retain site-specific characteristics of bladder production and other morphological traits. It was concluded that these traits are under the control of genotype and/or the environment of the turion-forming plants rather than under the control of the environment under which turions develop into plants.

Several experiments were conducted in which turions from the same site were exposed to different concentrations of nutrients and prey. Feeding regime and nutrient solution strength did not significantly affect morphological measurements used as indicators of prey capture tissue development. Duration of dormancy (i.e. length of time before experiments were begun) did affect morphological measurements. Development of prey capture tissue observed in lab-grown plants was primarily explained by their sites of origin. Plants originating from sites thought to have lower nutrient levels exhibited more prey capture tissue than did plants originating from sites thought to be rich in nutrients.
I thank the members of my committee for their advice and encouragement: Dr. Vicki Watson (who read and commented on innumerable drafts), Dr. Dick Fritz-Sheridan (who asked imaginative questions), and Dr. Andy Sheldon (who saw this project through from the first, summer afternoon graph). I also acknowledge the support and initial advising of Dr. James Habeck. Dr. Susan Knight provided invaluable culturing suggestion from her research with Utricularia, for which I am most grateful. Dr. Jack Stanford provided information on sites and facilitated use of Biological Station equipment. Dr. Dave Patterson helped with data analysis, and Mr. Dick Lane with preparation of computer files.

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Chapter One

Introduction

Carnivorous plants have been studied for years, both as objects of popular curiosity and as subjects for physiological research, because of the paradox they represent as "heterotrophic autotrophs" (Lüttge, 1983). While the plants are now known to absorb nutrients from captured prey, the necessity of these supplements for plant survival and reproduction is still a matter of debate (Lüttge, 1983; Sorenson and Jackson, 1968). Some species are obligate carnivores while others seem to be facultatively carnivorous (Skutch, 1928), growing indefinitely without ancillary resources, although perhaps not as vigorously as with prey inputs, or not to reproductive stages (Arber, 1920; Dore Swamy and Mohan Ram, 1971; Sorenson and Jackson, 1968).

The costs and potential benefits of carnivory are also not clear, and seem to vary with the fertility of particular habitats (Benzing, 1987). Prey-trapping
structures are thought to be modified leaves (Juniper, 1986), so that ontogenetic costs of production are perhaps not high. However, traps are less suitable for photosynthesis than are leaves, especially the more advanced trapping mechanisms (Benzing, 1987), so that a high return in terms of nutrients is necessary to compensate for the resource outlay.

Resources shunted to trap production may diminish the pool available for flowering, fruiting, and general growth (Bloom, Chapin, and Mooney, 1985), but the ability to supplement inorganic nutrient sources may allow these plants to survive in areas where non-carnivorous plants are poor competitors. These areas are most likely to be those which are limited by nutrients and not by light, water or some other factor, since the carnivorous habit can only supplement nutrient supplies (Benzing, 1987). In short, the costs must be outweighed by the benefits in areas where carnivorous plant species are common and populations are large (Benzing, 1987; Heslop-Harrison,
The development of a strategy to mitigate substrate nutrient paucity raises questions of resource allocation in these plants: how does a plant divide its resources between formation of prey capture tissue (PCT) and other tissues under varying environmental conditions, and how flexible is this resource allocation?

In a nutrient-poor environment, PCT development requires no more materials than it does in a nutrient-rich environment. But, energy costs to obtain these materials might be greater due to their relative dilution. However, the benefits of ancillary resources should be greater in the extreme environment than in an environment where nutrients are readily available. That is, both the costs and benefits of trap possession probably decrease as nutrient availability increases. Figure 1 shows these cost-benefit relationships, and suggests that carnivory is only adaptive in habitats with low to moderate nutrient availabilities. A carnivorous
Figure 1. Hypothetical Changes in Costs and Benefits of Bladder Production in *Utricularia vulgaris* as Nutrient Availabilities Increase

Legend:

Material costs ——

Material and energy costs ————

Gross benefits (i.e. relative importance of nutrients gained from carnivory) ·········

Net benefits (i.e. gross benefits - material and energy costs) ————
plant species would be expected to allocate more resources to PCT development in its nutrient-poor habitats, and more to non-PCT when growing in nutrient-rich sites. Indeed, Givnish et al. (1984) report that some carnivorous plants produce only non-PCT, or tissue with reduced carnivorous function, during seasons when nutrient availability is not the limiting factor to growth.

My research centered on this allocation question, with respect to the aquatic carnivorous plant, *Utricularia vulgaris* L.: do *U. vulgaris* plants growing in waters of low nutrient availability allocate more of their carbon resources to PCT production (bladders) than do *U. vulgaris* plants growing in waters of greater nutrient availability? Potential sources and sinks of energy and materials in *U. vulgaris* are diagrammed in Figure 2.

To investigate the above question, one needs to know the nutrient and prey levels to which a plant is exposed.
Figure 2. General Morphology of *Utricularia vulgaris* Showing Energy and Material Source and Sink Compartments

**Sources:**
- flowers
- fruits
- foliage
- turions
- stem bladders
- primary bladders
- secondary bladders
- symbiont N fixers

**Sinks:**
- production, photosynthesis, maintenance
- respiration, maintenance
- meristems

*production, photosynthesis, maintenance*
Since field sampling for nutrient levels is fairly ambiguous, and for prey levels even less conclusive, due to patchiness in space and time (Wetzel, 1983), I raised _U. vulgaris_ under controlled laboratory conditions.

Bladderworts can be raised under controlled conditions from turions, embryonic plants that arise vegetatively on the "parent" plant in fall, are dormant in winter, and develop into mature plants in spring. Turions are protected by a layer of mucilage, thus bladders are axenic. The dormancy of turions can be broken experimentally by high temperatures (Winston and Gorham, 1979a.)

Because turions already possess bladders, a preliminary question must be addressed before the above prediction can be examined, namely, is bladder production controlled genetically, controlled by the conditions to which the turion-forming "generation" was exposed, or controlled by the conditions in which the plant develops from the turion? Part of my research focused on this
problem of control of bladder production.

While much work has been done on carnivorous plant
taxonomy, morphology, and trapping physiology, only a few
studies have examined the effects of prey nutrients on
growth in carnivorous plants, and even fewer have
addressed resource allocation (Bosserman, 1983; Luttge,
1983; Pringsheim and Pringsheim, 1962). In this study,
I used laboratory and field experimentation to compare
resource allocation to PCT by *Utricularia vulgaris*
plants under differing prey and nutrient regimes.

My study consisted of three parts:

1. Summer field collections of mature *U. vulgaris*
plants to compare morphological characters and extent
of PCT tissue in plants from different sites.
2. A common garden experiment to compare development
of PCT and other tissues in plants grown from turions
collected from two different sites, when these
turions were grown under the same dissolved nutrient
conditions, without prey supplements.
3. A "diet" experiment to compare the effects of different dissolved nutrient levels and feeding regimes on development of PCT and other tissues in plants grown from turions collected from two different sites.

These three experiments were designed to examine the degree of development of PCT under nutrient-poor and nutrient-rich conditions, i.e. to test my resource allocation prediction that a greater proportion of resources are allocated to PCT under nutrient-poor conditions. The experiments also would show whether U. vulgaris plants respond to ambient conditions despite past history. The experiments would not distinguish whether any influence of past environment was due to "parental" genotype, to "parental" developmental environment, or both.
Chapter Two

Study Organism

*Utricularia vulgaris*, the greater or common bladderwort, is an aquatic, floating, rootless, carnivorous plant (Hitchcock and Cronquist, 1973). It is a member of the family Lentibulariaceae, which includes other carnivorous plant genera. The genus *Utricularia* holds about 250 species, including other floating aquatics like *U. vulgaris*, semi-terrestrial and terrestrial forms, and epiphytes. The genus is thought to have evolved by the Pliocene era (Muller, 1981), and fossil turions of *U. vulgaris* have been found from the German interglacial period (Jung, 1976). The chromosome number of *U. vulgaris* is $n = 18$ to 20 (Kondo, 1969).

*U. vulgaris* is circumboreally distributed in slow-moving streams, lakes, ponds, boggy areas, and wet meadows, and is fairly common (Ceska and Bell, 1973; Meyers and Strickler, 1979; Rossbach, 1939). Its
habitats range from acidic through neutral to alkaline, and vary in temperature, nutrient availability, light availability, and associated species (Ceska and Bell, 1973; Rossbach, 1939; this investigation).

The growth form of *U. vulgaris* is stoloniferous, with side branches at a distance from the apical meristem(s). Leaves arise alternately, are highly dissected and generally two-parted at the base, with a few teeth on some segments (Ceska and Bell, 1973; Crow and Hellquist, 1985; Fig. 2.) However, the terms "stem" and "leaf" are used mainly for convenience since organ morphology in *U. vulgaris* is not readily homologous with other vascular plants. The vegetative plant has been suggested to be entirely a root system, a stem system, or a single, much divided leaf, as well as a stem and leaf combination (Arber, 1920; Sculthorpe, 1967).

*U. vulgaris* grows at branch tips and decays behind, often fragmenting into several pieces, each of which can survive and propagate. Indeed, the vegetative
propagation capabilities of *U. vulgaris* are incredible: almost any cell, whether of flower, leaf, stem, or turion leaf (see below), can become meristematic, dividing to form a new stem and eventually populating an entire pond (Arber, 1920; Goebel, 1904 and Glück, 1906 in Sculthorpe, 1967).

*U. vulgaris* also reproduces sexually, through the formation of yellow, bilaterally symmetric flowers which are supported on a scape above the water surface (Hitchcock and Cronquist, 1973). Flowers may be self-fertilizing (Winston and Gorham, 1979a) or chasmogamous. Pollen is stephanocolporate (Kapp, 1969; Thanikaimoni, 1966) and fruits are capsules with many small, endospermless seeds (Ceska and Bell, 1973; Hitchcock, Cronquist, and Ownbey, 1959).

*U. vulgaris* is perennial, overwintering in cold climates through the formation of turions, or winter buds (Rossbach, 1939; Sculthorpe, 1967). Turions are clusters of leaves with condensed internodes that are formed in
late summer, or when the plant experiences cold, nutrient or water stress (Maier, 1979; Sculthorpe, 1967). Turions are covered by coarser leaves, turn brownish when mature, and possess a thick coating of mucilage. These structures usually remain attached to the senescing parental stem (which by autumn is only a tough vascular strand within a spongy cortical layer, most leaves having abscised), and are pulled downward by this stem, so that they overwinter below the ice (Arber, 1920; this investigation). With further decay of the old plant, the turions are released and float to the surface. As temperatures warm in the spring these turions reflex, green up and elongate into new plants (Winston and Gorham, 1979a). Turions may fragment and single coarse leaves may each give rise to several plantlets. Turions are high in starch and stored materials, and therefore can withstand drying and freezing well (Maier, 1973; Winston and Gorham, 1979a).

_Utricularia vulgaris_ has a reduced vascular system,
consisting mainly of a few, poorly developed tracheids and small groups of phloem elements. There is an endodermis, and the cortex has lacunae and some fibrous ground tissue (Sculthorpe, 1967). It follows the C-3 photosynthetic pathway, and bladders are photosynthetic (Lüttge, 1983). Photosynthetic rates are probably low relative to terrestrial plants (Thai, Haller, and Bowes, 1976).

The common bladderwort captures crustaceans, insect larvae, fish fry, rotifers and other aquatic organisms, sometimes including algae and the vascular plant Wolffia, in small bladders, or utricles, by suction (Botta, 1976; Hegner, 1925; Roberts, 1972). The utricles are of three types: stem bladders, occurring in clusters of zero to five at petiole bases; primary bladders, usually larger, 0.5 to 5 mm long, occurring singly near the principal bifurcations of each leaflet; and secondary bladders, smaller, and occurring at distal leaf divisions (Hitchcock and Cronquist, 1982; Wallace, 1977, 1978;
this investigation; Fig. 2). These three types are all functional and capture prey of different sizes (Wallace, 1977).

Bladders vary in size and number per leaflet, and are formed while the leaflet is still part of the bunched, meristematic tip. They seem to arise from both leaf and stem tissue, but exact homology is under contention (Arber, 1920; Heywood, 1978). Utricles are light to bright green when young, sometimes with a reddish, anthocyanin shading, becoming violet to black with age and use (Botta, 1976; Lloyd, 1933; this investigation).

Utricles consist of a thin layer of cells, nearly transparent, with many two- and four-armed glands that secrete digestive enzymes (acid phosphatase, protease, esterase) and absorb digestive products (Slack, 1979). Utricles are attached to the stem and the leaflet arms by short stalks and easily abscise, with age as well as poor growing conditions, algal infections, and excessive
movement or handling (Lloyd, 1933; Sorenson and Jackson, 1968; this investigation). Bladders have a trap door that seals tightly, and two types of hair-like organs, called antennae and bristles (Darwin, 1897), project from this area. Antennae are long, branched processes which may help to guide prey to the traps, or to protect the tripping mechanism from too large aquatic visitors (Johnson, 1987; Meyers and Strickler, 1979). Bristles are non-branched, shorter organs which function as triggers to open the door, allowing an inrush of water and prey (Hegner, 1925; Lüttge, 1983; Sydenham and Findlay, 1973). The bladder cells actively transport chloride anions outward, and sodium and potassium cations inward, resetting the bladder, and forcing it to assume a concave shape when ready to fire. There may also be an electrical, excitatory step in trap firing (Sydenham and Findlay, 1973).

Prey live for varying periods of time within the bladders, and are digested gradually (Arber, 1920). Some
algal species and protozoans not only survive, but grow and multiply within the utricles. Some of these algae are cyanophytes, and fix nitrogen which is then released to the plant (Botta, 1976; Wagner and Mshigeni, 1986). Some large prey, such as mosquito larvae and fish fry, are caught by head or tail and ingested in segments (Hegner, 1925).

*Utricularia* does not have major economic value, although it is eaten by a few fish and provides shade and shelter for them, and is used as fodder for pigs and cattle (Sculthorpe, 1967). The plants also help control mosquito larvae populations (Jha, Jha, and Kumari, 1978; Schwartz, 1974; Skutch, 1928), help control the spread of schistosomiasis in the Caribbean by capturing flukes (Gibson and Warren, 1970), and may help control the spread of radioactive waste (Deksbakh, 1964). *U. vulgaris* may also have some value as a "green fertilizer" in rice fields because of the cyanophyte nitrogen fixers associated with it (Wagner and Mshigeni,
Chapter Three

Literature Review

The phenomenon of carnivory in plants has prompted investigations into why it might be adaptive, and what selection pressures might have led to its evolution. The general consensus is that carnivory fills macro- and micronutrient needs for plants in low nutrient environments (Folkerts, 1982; Heslop-Harrison, 1978). Carnivorous plants seem to have adequate photosynthetic pigments for securing carbon (Pringsheim and Pringsheim, 1962), and many carnivorous plants have reduced root systems suggesting prey inputs are compensatory (Schmucker and Linnemann, 1959, in Aldenius, Carlsson and Karlsson, 1983).

Heslop-Harrison (1978) reported that nitrogen and phosphorous are important gains from carnivory, but which is more important depends on the habitat (Benzing, 1987). On the other hand, Folkerts (1982) suggested that the acid nature of many carnivorous plant habitats decreases
micronutrient availability, hence carnivory may give its
greatest benefit in securing these elements. He also
felt that carnivory may only be important when the
habitats are under nutrient stress (e.g. when Gulf Coast
pitcher plant bogs have not been fire-swept in a long
time.)

I. Feeding Experiments

Feeding experiments have been performed on several
species of carnivorous plants, and differing results have
been found. Aldenius et al. (1983) grew *Pinguicula*
*vulgaris* L. on local soil and enriched local soil, with
and without insect supplements. They found that both
watering with a complete nutrient solution and addition
of insects caused increased dry weights, increased
numbers and lengths of leaves, and increased nitrogen
and phosphorous tissue concentrations. They concluded
that *P. vulgaris* was using nitrogen and phosphorous
from the captured insects, as well as some other
substance that helped the roots take up nitrogen, perhaps iron or molybdate ions. Their experimental plants came from two sites that differed in nutrient richness, and the benefits of the insect enhanced diet were greatest in the plants from the richer site. This result does not agree with the general hypothesis that the most benefits of carnivory are realized by plants from the poorest sites (Chandler and Anderson, 1976; Givnish et al., 1984; Sorenson and Jackson, 1968). Aldenius et al. suggested phenological variation between the two sites might be a confounding variable, but also noted that, if a prey input increased root uptake of minerals, then richer soils would lead to better growth.

Karlsson and Carlsson (1984) also worked with *P. vulgaris*, simulating insect capture by applying blocks of agar containing nitrogen, phosphorous, or microelements to the leaves. They found that phosphorous blocks induced biomass increases, and concluded that phosphorous was the most important supplement gained by
carnivory in the common butterwort. They also reported that application of nitrogenous agar caused an increase in root to leaf weight ratios.

For another species of butterwort, *Pinguicula lusitanica* L., Harder and Zemlin (1967c) found increased leaf development, increased chlorophyll, and more flowers on plants grown on nitrogen- and phosphorous-deficient inorganic media that were given *Drosophila*, egg yolk, or ammonium phosphate. Untreated plants did not flower. Harder and Zemlin (1968) also found that *Pinus* pollen given to *P. lusitanica* leaves caused an increase in number of leaves and diameter of rosettes, as well as slowing aging, promoting flowering, and deepening the plants' green color. Nonetheless, these researchers (1967c) felt that unambiguous proof for enhancement of plant development by captured prey inputs had only been given for *Drosera* and *Utricularia*.

Chandler and Anderson (1976) similarly experimented with species of *Drosera*, growing plants in sand cultures.
deficient in nitrogen, sulfur, phosphorous, or the micro-elements, and feeding with Drosophila. Using D. binata Labill., they found that optimal growth occurred with insect supplements and a nitrogen-deficient medium, while added nitrate inhibited growth. Chandler and Anderson found increased growth in D. whittakeri Planch. when flies were given to plants lacking root access to any nutrients or to inorganic sources of nitrogen and sulfur, but not in plants denied phosphorous or microelements. However, Drosophila supplementation did cause increased phosphorous tissue concentrations on phosphorous deficient and complete media.

For another tuberous species of sundew, Drosera erythrorhiza Lindl., Pate and Dixon (1978) found Drosophila to be an effective source of nitrogen and phosphorous.

Fabian-Galan and Salageanu (1969) observed translocation of carbohydrates and amino acids from prey to the plant in Drosera capensis L., and from prey in
mature traps to growing points in *Aldrovanda vesiculosa* L., but not from young traps.

Christensen (1976) found that *Sarracenia flava* L. plants deprived of soil nutrients and prey were fairly small and showed some chlorosis. Plants grown on poor soil and fed insects had increased tissue concentrations of nitrogen and phosphorous, but not of calcium, magnesium, or potassium. Plants grown with abundant fertilizer and given insects did not show increased tissue concentrations relative to plants grown with fertilizer but not given insects. Christensen hypothesized that insectivory may interfere with nutrient uptake when nutrients are abundant.

Hermann, Platt, and von Ende (1987, pers. comm.) found increases in growth and clone numbers in *S. flava* plants that were fed. They did not observe effects until a year or more had elapsed but suggested the impacts of withholding prey could be ameliorated by the underground storage organ this species possesses.
Plummer and Kethley (1964) observed absorption of amino acids, peptides, and other nutrients from prey by leaves of *S. flavum*. They decided that the gains from carnivory may be greater for immature plants than for adults.

Roberts and Oosting (1958) reported that various previous experiments on *Dionaea muscipula* Ellis were inconclusive, and found that fed plants in their study showed more vigorous vegetative growth, but that unfed plants watered with distilled water did better than unfed plants watered with an inorganic nutrient solution (excessive concentrations or wrong proportions of nutrients were suggested as a possible cause.)

Observers of *Utricularia*, like those of terrestrial carnivorous plants, have noted more vigorous growth in plants which capture prey. Skutch (1928) reported that putting asparagin, albumen or flesh extract into bladders with pipettes resulted in increased chlorophyll in bladder antennae and larger bladders (including "giant"
bladders in *U. vulgaris* that measured 6.2 mm in length). Also, several adventitious shoots arose from the leaves bearing treated utricles. Another consequence of the artificial feeding was formation of two bladders per stalk and stimulation of leaf apices to form bladders. Skutch recorded the results of Büsgen's (1888) feeding trials as well: treated *Utricularia vulgaris* plants were longer and developed more leaves than unfed plants, and in one series of experiments, untreated plants formed unseasonal turions while fed plants grew well.

One of the classic feeding studies of *Utricularia* was undertaken by Pringsheim and Pringsheim (1962). Their *U. exoleta* R. Braun plants showed good vegetative growth in inorganic nutrient solutions but only flowered if organic compounds were added (peptone and meat extract). Pringsheim and Pringsheim (1967, in Sorenson and Jackson, 1968) further found peptone and beef extract necessary for good vegetative growth in *U. minor* L. and *U. ochroleuca* R. Hartman, but could not induce flowering
with organic additives.

Sorenson and Jackson (1968) experimented with *U. gibba* L. in magnesium- and potassium-deficient and complete media, and fed paramecia to some plants. They discovered that feeding did not cause a growth increase in plants in complete media and only caused a small increase in plants in the magnesium-deficient media. However, fed plants in their potassium study, in both complete and incomplete media, did elongate significantly more than unfed plants. Paramecia treatments also increased the number of internodes, and allowed formation of more bladders, but the latter result was confounded by differing intensities of algal infection which caused bladder abscission. Sorenson and Jackson's experiments supplied live prey, so that utricles were activated in the study, which was not the case in other research reviewed here.

Dore Swamy and Mohan Ram (1969, 1971) grew *U. inflexa* Forsk. axenically and tried adding beef extract, casein
hydrolysate, peptone, tryptone, and yeast extract. All of these organic nitrogen sources enhanced vegetative growth, but depressed flowering, and yeast extract completely inhibited flowering. Dore Swamy and Mohan Ram observed flowering with and without glycine in the medium, and concluded that animal protein is not necessary for flowering in U. inflexa. They also found that beef extract, casein, and tryptone delayed bladder abscission, while high light (6000 lux) promoted bladder reddening and abscission. Mohan Ram, Harada, and Nitsch (1972) confirmed that U. inflexa could use nitrate as its nitrogen source.

Harder (1963), raising U. exoleta in a mineral nutrient solution and treating some plants with autoclaved Daphnia infusions, found that untreated plants became dormant, while supplemented plants flowered. Peptone extract also induced flowering. He inferred that natural carnivory is not a strategy for nutrient assistance, but rather a source for
reproductive cycle requirements. Harder and Zemlin (1967a), however, induced flowering in U. stellaris L. without animal supplements.

Harder (1970a) tried various proportions of nutrient solution and autoclaved Daphnia (ranging from 18 to 4500 Daphnia per 100 ml of solution) on five species of Utricularia, and found increases in dry weights of U. minor, U. exoleta, and U. ochroleuca when 300 or more Daphnia were administered. Daphnia decoctions induced flowering in U. exoleta, but no flowering was observed for U. vulgaris, U. minor, or U. ochroleuca whether or not these species were "fed".

Johnson (1987) noted that absorbed nutrients were rapidly moved to the growing points of Utricularia, and Coleman, Lollar, and Boyd (1971) found quick movement of phosphorous from bladders to stems and leaves when U. inflata Walt. plants were exposed to radioactively labelled ostracods. They also stated that the carnivorous absorption pathway is probably more
important than the foliar absorption route only in infertile waters.

Harder and Zemlin (1967c) addressed the possibility of carnivorous plants using carbon from captured prey. They found that growth in *U. stellaris*, *U. exoleta*, *U. minor*, *U. ochroleuca*, and *U. vulgaris* was enhanced by saccharose and glucose, and to a lesser extent by fructose, maltose and cellobiose. Flowers were more abundant on plants grown in solutions with added sugar. These effects were seen in plants grown under light and dark conditions, but were more apparent in the light-cultured plants. Harder (1970a) determined that sugar added to nutrient solutions had a greater effect on growth and flowering in these five species than did *Daphnia* decoctions. Harder and Zemlin (1967b) found growth promotion by sugar in a non-carnivorous submerged aquatic, *Apogonetum distachius*, as well. Harder (1970b) observed dry weight increases in *U. minor* plants grown in an inorganic solution and beef extract when sugar and
acetate were added. The extent of the increase depended on concentrations of the sugar and acetate: more acetate allowed lower sucrose concentration for maximum effect and vice versa. With sucrose supplementation, he also recorded growth in plants held in darkness, albeit less growth than in plants exposed to light.

Similarly, Dore Swamy and Mohan Ram (1969) found that increased sucrose levels in growth media for *U. inflexa* resulted in development of lateral branches by release of apical dominance, and that higher levels of sucrose induced morphological change: 6% caused bushy plants with short internodes, and 8% caused bushy, dark green plants with small pigmented bladders and reduced flowering. On the other hand, they (1971) recorded poor growth in plants grown in darkness on a medium including sucrose and glycine: small leaves, light green coloration, and elongated stems. Bladders, however, were no different from those of light-grown plants.

For *Drosera*, Chandler and Anderson (1976) determined
by low level light experimentation that insects were not an important carbon source.

In summary, the literature on plant feeding research suggests that carnivorous plants derive nitrogen, phosphorous, sulfur, and some micronutrients from their prey, but that the actual nutrient of greatest importance depends on the species and the environment. Further, the necessity of ancillary resources for completion of the life cycle also depends on species and habitat. Lastly, some carnivorous plants can use the carbon skeletons of prey, but none have been found to survive without photosynthesis.

II. Constraints and Confounding Factors

In the literature, there has also been some mention of constraints on the benefits of carnivory, and of factors confounding the demarcation of such gains. Moeller (1978) noted that carbon may be limiting for Utricularia purpurea Walt., which does not use
bicarbonate. Thus, experiments which do not provide sufficient inorganic carbon in a form the experimental species can use may not find the growth increases expected from insect dietary additions.

Botta (1976) listed species of cyanophytes that survive indefinitely in bladders of *Utricularia obtusa* Sw., *U. platensis* Speg., and *U. foliosa* L., and Bosserman (1983) mentioned nitrogen fixation by periphyton associated with *U. purpurea*, *U. juncea* Vahl, and *U. inflata*. Wagner and Mshigeni (1986) measured nitrogen fixation by epiphytes and bladder-dwelling algae of *U. inflexa* and suggested the process is intensive enough to give the association potential as a biofertilizer. They also raised the possibility of nitrogen contributions to *Utricularia* by heterotrophic bacteria. Consequently, *Utricularia* and other aquatic or phytotelm (water-holding) carnivorous plants may have a third nitrogen source.

Rossbach (1939) reported that *Utricularia* species of
northern regions which form turions usually develop fewer flowers than their more southerly conspecifics, and only infrequently produce fruit. Thus turions may be resource sinks not considered in feeding experiments. Similarly, Skutch (1928) explained that the turion food supply may compensate for prey inputs in recently sprouted plants, another factor to be considered in analysis of feeding experiment results. Tubers as nutrient sources and sinks in *Drosera erythrorhiza* were noted by Pate and Dixon (1978).

The photosynthetic contribution of trapping organs (Hegner, 1925; Lüttge, 1983) also confounds cost/benefit analyses.

Lastly, Moeller (1980) discussed the effects of temperature on growth in *U. purpurea*, and Maier (1979) showed effects of light intensity on production in *U. vulgaris*. These and other environmental factors interact with substrate fertility and prey nutrient inputs to produce observed growth and development of
III. Evolutionary Aspects

Some recent papers have explored models for the evolution of carnivory and attempted to conduct cost/benefit analyses. Thompson (1981) compared insectivory with myrmecophily (ant-fed plants), suggesting both nutrient supplementation strategies evolved in response to similar ecological conditions. He noted that insectivory is advantageous in moist, low nutrient habitats, since such species use water freely in glandular secretion and absorption processes, while epiphytic myrmecophily is the workable design for open canopy forest sites where dryness prohibits insectivory.

Benzing (1986) agreed that ecological factors limit carnivorous plants to moist, exposed habitats, where photosynthesis is not limited and costs for secretory lures and other trapping implementia are not excessive.
He further stated that myrmecophily is a less costly strategy and therefore found in more stressful habitats.

Juniper (1986) postulated that the origins of carnivory are polyphyletic, and present convergence represents a limited number of techniques to compensate for habitat sterility. He noted that elements of the suite of carnivory characters are found in many other plants, and only in situations where carnivory would be advantageous did the entire syndrome evolve.

Bloom et al. (1985) applied economic theory to calculate how plants should develop in order to maximize growth in their environments, and pointed out the necessity of considering nutrients and water as currency as well as carbon—the usual base for analysis. They deduced that carnivory occurs when stocks of water and nutrients are imbalanced. Growth in nutrient-poor environments must be slow, but plants of these habitats adjust for their supply levels and are less flexible in allocation patterns than are plants of more fertile
habitats. Nutrient-starved plants were also predicted to show less sequestering of resources for sexual reproduction.

Givnish et al. (1984) suggested the main advantage of carnivory is increased photosynthesis via mineral nutrient supplementation allowing increased photosynthetic rates and/or increased numbers of photosynthetic units. They hypothesized that photosynthetic benefits will level out when factors other than nutrients become limiting. This supports the rule of thumb mentioned earlier, that prey capture is most advantageous in the least rich sites. Givnish et al. concluded that the greatest benefits of carnivory will accrue to plants in moist, sunny, low nutrient habitats, while in dry or shaded low nutrient habitats, benefits will be less and level out sooner.

Benzing (1987) added that carnivory is rare because capture and absorption of prey is not an economical way to supplement nutrient uptake in most environments.
These "generally unfavorable energetics" also prevent carnivorous plants from being vast, dominant communities.
Chapter Four

Study Sites

Plants and turions were collected in Flathead and Lake Counties of Montana. Sites varied in size, water chemistry, plant species composition, and size and vigor of *Utricularia vulgaris* populations. Turions for laboratory experimentation were collected from three sites: East Bay of Flathead Lake, McWenneneger's Slough, and Tykeson Pond; plant materials from these as well as three other sites were examined: Daphnia Pond, Loon Lake, and "Tykeson's Kettle". Locations of these sites are shown in Figure 3.


Water in East Bay is clear beyond the depths at which *Utricularia* is found. Flathead Lake is classed as
Figure 3: Study Site Locations

1. East Bay, Flathead Lake
   Lake County
   T22N R19W Sec. 5-6

2. McWenneger's Slough
   Flathead County
   T28N R20W Sec. 6

3. Tykeson Pond
   Lake County
   T26N R19W Sec. 16

4. Daphnia Pond
   Lake County
   T26N R19W Sec. 1

5. Loon Lake
   Lake County
   T26N R19W Sec. 10

6. "Tykeson's Kettle"
   Lake County
   T26N R19W Sec. 15
oligo-mesotrophic (Stanford, Stuart, and Ellis, 1983), but East Bay itself is probably mesotrophic. (This classification, and the trophic levels for the other sites, are based on one-time water chemistry measurements, including conductivity, pH, alkalinity, and dissolved oxygen, as well as on water color and hydrophyte species composition.) The substrate is sandy in open water, silty under Typha stands. *U. vulgaris* is found in several locations within East Bay: among the Typha stands, in open, shallow water near Typha, and in windrows with other floating macrophytes and detritus. *U. vulgaris* is not a dominant plant in this site (cover 5 to 25%), but is found in small patches.

McWennenegger's Slough is a large shallow slough, wooded on the southeast, open to the north and west, which contains a luxuriant, diverse plant assemblage. Besides *U. minor* and *U. vulgaris*, species found in the slough include: *Carex* spp., *Ceratophyllum demersum* L., *Chara* sp., *Elodea nuttallii* (Planch.) St. John, *Lemna trisulca*

The summer Secchi disk transparency is 0.5 m, and the water is meso- to eutrophic. The substrate is coarse and sandy in some places, a thick silt in others. U. vulgaris grows at various depths in the Slough, among the other macrophytes. Plants are large and healthy, growing in patches, varying from 25 to 50% cover. Of the sites described, and others in Lake County that were visited, McWenneneger's Slough is the mother lode for U. vulgaris—plants are by far the largest, longest, and most vigorous there.

Tykeson Pond is a small, shallow, somewhat dystrophic pond surrounded by open forest to the south and east and by logging roads to the north and west. It is dominated by Menyanthes trifoliata L., and also hosts Carex spp.,
Lemna turionifera, Nuphar lutea, Phalaris arundinacea L.,
Potamogeton natans L. and other Potamogeton spp.,
Potentilla palustris (L.) Scop., and U. vulgaris. The
water is soft and dark, with a summer Secchi depth of
0.25 m. Sediments are peaty, brown, and coarse.
U. vulgaris grows densely with 50 to 75% cover.

Daphnia Pond is also small and shallow, a late
successional pond dominated by the emergent plants
Phalaris arundinacea, Scirpus sp., and Typha latifolia.
Other macrophytes in Daphnia Pond include: Ceratophyllum
demersum, Lemna turionifera, Myriophyllum spicatum,
Nuphar lutea, Polygonum amphibium, Potamogeton natans L.
and other Potamogeton spp., and U. vulgaris. The summer
Secchi depth in the dark, dystrophic water is 0.18 m.
At the steep bank edges, the substrate is gravelly, but
in most areas there is an organic, mucky bottom.

U. vulgaris seems localized in distribution in
Daphnia Pond, contrary to reports from earlier years
(Sheldon, 1987, pers. commun.). During 1987, U. vulgaris
occurred in the south end of the pond, among the *Typha* stems and in openings in the emergent stands. Plants grew singly in the cattails and in small groups in the openings, with cover increasing from 5 to 25% to 25 to 50% respectively.

Loon Lake is a forested lake with an extensive mat developing on the northwest side. Aquatic vegetation is characterized by *Carex* spp., *Chara* sp., *Elodea canadensis* Michx., *Myriophyllum spicatum*, *Najas flexilis* (Willd.) Rost. and Schmidt, *Nuphar lutea*, *Polygonum amphibium*, *Potentilla palustris*, *Scirpus* sp., *Typha latifolia* and *U. vulgaris* (with *U. minor* as well, on the mat). The water is clear to the depths at which *U. vulgaris* is found, about 0.80 m, and the lake is mesotrophic. The substrate is silty and marl is present. *U. vulgaris* grows singly, and is scattered, with a cover ranking of 1 to 5%.

"Tykeson's Kettle" is an unnamed, more or less mesotrophic, sunken pond in the forest adjacent to
Tykeson Pond. Much of its surface is covered thickly by *Lemna turionifera*; other macrophytes present are *Chara* sp., *Myriophyllum spicatum*, *Nuphar lutea*, *Phalaris arundinacea*, *Potamogeton* spp., and *U. vulgaris*. Where there is no *Lemna*, the summer Secchi depth is 0.5 m. The sediments are brown, organic and silty. *U. vulgaris* grows in small patches, 5 to 25% cover.

All sites described, except McWenneger's Slough, have been created or affected by glacial activity; the Slough is an artifact of meanders of the Flathead River (Alt and Hyndman, 1986). All six areas are subject to ice formation in the winter, and East Bay is also subject to major water level fluctuations due to drawdown for hydroelectric purposes. East Bay further differs from the other sites in being the only one which is influenced by water inputs other than ground water and precipitation, i.e. the others have no inlets or outlets.

Climate is similar for all sites, a "modified North Pacific Coast type", with one-half the annual
precipitation falling between May and July (NOAA, 1985). The mean yearly maximum temperature is 55.8 °F, the yearly minimum is 33.0 °F. Precipitation averages 15.36 inches per year, excluding an average 50.8 inches of snow. Annually, about 71 days are clear, 80 partly cloudy, and 214 cloudy (Kalispell, Montana averages; NOAA, 1985).
Chapter Five

Methods and Materials

I. Summer Field Collection

I gathered intact plants of *Utricularia vulgaris* at six sites (Fig. 3) in late July and August of 1987, and transported these samples in local water. Within a few days of collection, I determined the following for the sample plants: stem diameter at one representative point, length of plant or shoot section (some plants were broken during handling), number of leaves (leaflet pairs) per plant, and number of primary bladders per leaflet for at least 13 leaflets on each plant. Although I counted bladders for the current year's growth of each plant, with handling, some bladders abscissed. Consequently, I estimated the potential number of bladders per leaflet based on a growth pattern discerned from previous observations. I did not count stem bladder or secondary bladder positions since their
presence and number are more variable than those of primary bladders, and since some of them had abscissed also.

I computed summary statistics for the variables measured and for indices computed from them: leaflet pairs per cm of stem, number of bladders (or positions) per plant (average bladders per leaflet x two leaflets per leaf x total leaves) and bladders (or positions) per cm of stem (total bladders/length). I drew boxplots for these variables for each site, and conducted a multivariate analysis of variance (MANOVA).

My data were quite variable and may have violated the MANOVA assumptions, depending how conservatively one follows the assumption guidelines (Ott, 1984; Patterson, 1988, pers. comm.). Specifically, the variance was not common to the different sites, and this inequality was made worse by the small and unequal sample sizes. Samples were neither random nor independent. The assumption of normal distribution for each variable in
the population was probably adequately met. Because the assumptions of parametric statistics may not have been met, I also conducted a nonparametric MANOVA.

Because of the small sample sizes, I could not test for differences among populations for all variables measured (Patterson, 1988, pers. comm.). I chose four variables that would roughly indicate development of PCT versus other tissues and allow testing of my allocation hypothesis: bladders per leaflet, per plant and per cm, and leaflet pairs per cm. In my laboratory experiments, I used slightly different, more appropriate, indicator variables for PCT development, but I did not have the necessary data to compute these indicators in the Summer Field Collection.

I assumed that dissolved inorganic nutrient levels regulate allocation of resources to PCT, while carnivorous nutrient inputs control the amount of growth within the allocation framework. Plants receiving many nutrients via the carnivorous pathway might be expected
to decrease allocation of resources to PCT if overall (i.e. foliar and carnivorous) nutrient uptake was the regulating mechanism. However, the limited lifespan of traps suggests this is not the case. Bladders, for example, darken and decay with use, and *Dionaea* leaves may only catch three insects before becoming inactive (Slack, 1979).

A plant stimulated by low substrate nutrient availability to produce many traps will continue to be stimulated to allocate resources to PCT. The quantity of nutrients reaped by these traps will affect the amount of growth the plant can complete, and whether or not it can flower. Thus, carnivorous plants growing in nutrient-poor sites which have large populations of potential prey should exhibit high levels of PCT, but also be large-sized.

For *Utricularia vulgaris*, and other aquatic carnivorous plants, sites with few dissolved nutrients usually also have low prey populations. Accordingly,
based on my allocation hypothesis, I expected the greatest numbers of bladders per cm to occur in plants collected from the poorest sites. I expected bladders per plant to be highest in the largest plants, i.e. those from the richest site. Numbers of leaflet pairs per cm and bladders per leaflet should be intermediate for plants from both nutrient-poor and nutrient-rich sites, since good growth increases numbers of leaflet pairs and bladders per leaflet, while allocation to PCT does so as well.

Anomalous sites with low dissolved nutrient levels but high potential prey populations should produce *U. vulgaris* plants with fairly high values for all four indices. I did not examine prey availability at any of the sites.

II. Common Garden Experiment

In October, 1987, I collected *Utricularia vulgaris* turions from East Bay and McWenenger's Slough, by
severing the persistent stem of the summer growth 2-3 cm from the turion base. I selected plants haphazardly and took one (occasionally two) turions per plant. I transported the turions in local water in an insulated container.

I later rinsed the turions in tap water to remove algae, detritus, and mucilage, and placed them into aquaria filled with distilled water (separated by site). I put the aquaria into a controlled temperature room (CTR) where turions were exposed to about 450 ft-c fluorescent and incandescent light (General Electric light meter type 214) on a 14 hour photoperiod, with the temperature set for 30 °C. The dormancy-breaking procedure closely followed Winston and Gorham (1979a).

I added distilled water as needed to keep turions submerged. Turions from McWenneneger's Slough developed rampant algal coverings which I removed by rubbing and rinsing.

Due to temperature control difficulties, in one week
I moved the turions to a growth chamber (Percival model PT80) set for the same conditions, but with 850 ft-c of fluorescent and incandescent light.

When sufficient turions had begun to sprout (approximately 2 weeks after collection), I began the Common Garden Experiment. I placed nine sprouted turions from East Bay and nine from McWenneger's Slough into two trays (33.5 x 26 x 8.5 cm), one for each site, filled with nutrient solution.

I used Pringsheim and Pringsheim's (1962) nutrient solution throughout the growing period for this experiment, diluted to one-half strength to slow algal growth (Knight, 1987, pers. comm.). The nutrient solution formula by weight, in distilled water, is:

- \( \text{KNO}_3 \) 0.02%
- \( \text{(NH}_4\text{)}_2\text{HPO}_4 \) 0.002%
- \( \text{MgSO}_4\cdot7\text{H}_2\text{O} \) 0.001%
- \( \text{CaSO}_4 \) (saturated) 2 ml/100
- Minor element solution 1 ml/100

Minor element solution:

- \( \text{EDTA} \) 0.02%
Pringsheim and Pringsheim's solution uses MnSO$_4$.4H$_2$O; I substituted MnSO$_4$.1H$_2$O because it was more readily available. Approximate pH values for the nutrient solution were: 6.4 for one-half strength, (Orion Research Digital Ionalyzer/501), 6.3 for full strength, and 6.7 for one-tenth strength (the latter strengths were used in the Diet Experiment, described below).

The turion trays were kept in the CTR, set at 24 °C during the day, and 18 °C at night, under about 400 ft-c of fluorescent and incandescent light. I later transferred the plants to larger containers (53 x 23 x 14 cm).

I started a replicate of this experiment one week later, when more turions had sprouted, using 14 East Bay plants and 14 McWennoneger's Slough plants in 46 x 24 x 15
cm aquaria. Complete experimental design is shown in Figure 4.

Nutrient solution was added whenever needed to maintain levels, and nutrient solution was changed completely once in the Replicate 1 aquaria to control algal growth. No prey were offered to plants in this experiment.

After four weeks of growth I took a series of measurements on each plant: stem diameter at one representative point on each branch longer than 3 cm, or at three points along the stem if single-stemmed; length for each segment; number of leaflet pairs per segment; length of ten healthy, mature leaflets; number of bladders on 15 representative leaflets. Bladders tended to fall off with algal infection and handling, so I estimated the potential number of primary bladders per leaflet as before, again not counting stem or secondary bladder positions. I recorded wet (blotted) weights for each plant (Ohaus model B300 electronic digital scale)
Site of Turion Collection

<table>
<thead>
<tr>
<th>Replicate Experiment ran from</th>
<th>East Bay</th>
<th>McWenenger's Slough</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/28-11/27</td>
<td>9 turions</td>
<td>9 turions</td>
</tr>
<tr>
<td>11/4-12/5</td>
<td>14 turions</td>
<td>14 turions</td>
</tr>
</tbody>
</table>

Modified Pringsheim and Pringsheim (1962) nutrient solution at one-half strength and no prey for all treatments.

All treatments were exposed to summer conditions: 24 °C day, 18 °C night, 14 hour photoperiod, approximately 400 ft-c for four weeks.
and noted presence or absence of new turions.

I measured each plant in a large white enamel tray, with the plants in shallow water. Measurement precision was lowered by the water and by the flimsy nature of the plants. I dried all plants for about 24 hours at 35 °C and recorded dry weights.

I repeated the measurement process for plants in the second replicate experiment after they had grown for four weeks.

For both replicate experiments, I calculated summary statistics by site. I used the variables of the Summer Field Collection, plus leaflet length and bladders per gm (total bladders/dry weight). I also drew boxplots for the variables, for each site and each replicate. I analyzed the effects of independent variables (collection site, replicate experiment) on dependent variables (morphological measurements) using MANOVA, in order to consider overall variation simultaneously (Patterson, 1988, pers. comm.).
Since my data base was small, I again chose four key variables for the MANOVA: leaflet length, leaflet pairs per cm, and bladders per cm and per gm. If developing turions respond primarily to ambient conditions, there should be no significant differences between sites for these variables. However, if developing plants retain site-specific traits, it would be more difficult to test PCT predictions. Based on my allocation hypothesis, I expected plants grown from turions from sites thought to be low in nutrients to have higher numbers of bladders per cm and per gm (standardized measures of PCT development). I also expected these plants to have intermediate numbers of leaflet pairs per cm (leaflet pairs per cm can indicate good growth and/or PCT development) and shorter leaflets (leaflet length indicates general good growth). I expected turions from sites thought to be rich in nutrients to grow into plants with long leaflets, intermediate numbers of leaflet pairs per cm, and few bladders per cm and per gm.
Where the MANOVA showed an interaction between variables, I drew profile plots, using the means for each site and replicate experiment for the variables in question. Once again, my data and sample sizes were not in strict adherence to MANOVA assumptions, so I conducted nonparametric tests.

I used the categorical variable, presence or absence of new turions, to further verify the plants' capacity for response to ambient conditions. Presence or absence of new turions would also indicate the suitability of the growing conditions.

For this variable, I computed a chi-square test for replicate experiments separately and in combination. I also calculated Cramer's V (same as phi for the combined replicates), and the contingency coefficient. When the four treatments were considered separately, 25% of the cells had expected frequencies less than five, which makes chi-square accuracy, and that of the related statistics, borderline. Accordingly, I computed lambda,
III. Diet Experiment

In late October, 1987, I collected *Utricularia vulgaris* turions from Tykeson Pond and McWennenger's Slough. Some turions were allowed to germinate in distilled water under high temperatures, following methods outlined in the Common Garden Experiment. I rinsed the rest and refrigerated them at 1-3°C.

After two weeks, many McWennenger's turions had sprouted and I began the Diet Experiment. Germination of Tykeson turions was sporadic and unsuccessful, so these turions were not used. I placed nine McWennenger's sprouts in each of six treatment trays (33.5 x 26 x 8.5 cm), dividing turions so that each tray had plants of approximately equal size and developmental stage.

These trays were Treatments 1-6 in the experimental design shown in Figure 5. Trays contained about 5 l of...
Figure 5. Experimental Design for the Diet Experiment, Showing Treatment Number

<table>
<thead>
<tr>
<th>Nutrient Solution Strength</th>
<th>full</th>
<th>one-tenth</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1 15</td>
<td>3 18</td>
</tr>
<tr>
<td></td>
<td>7 21</td>
<td>10 24</td>
</tr>
<tr>
<td>10</td>
<td>5 14</td>
<td>6 17</td>
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<tr>
<td></td>
<td>9 20</td>
<td>12 23</td>
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<tr>
<td>100</td>
<td>2 13</td>
<td>4 16</td>
</tr>
<tr>
<td></td>
<td>8 19</td>
<td>11 22</td>
</tr>
</tbody>
</table>

fall winter fall winter

Experimental Season

All trays were exposed to summer conditions: 24°C day, 18°C night, 14 hour photoperiod, approximately 850 ft-c for four weeks, in a variety of growth chambers and controlled temperature rooms.

Treatments 5-12 started one week after Treatments 1-4.

Treatments 13-24 started eleven weeks after Treatments 1-4.

Treatments 13-18 were for turions collected from Tykeson Pond, all other treatments were for turions collected from McWenneneger's Slough.
one-tenth or full strength concentrations of the nutrient solution used in the Common Garden Experiment (Pringsheim and Pringsheim, 1962). One week later, I started replicate treatments, again using nine McWennonger's Slough turions per tray. These trays were Treatments 7-12.

I added nutrient solution when needed to Trays 1-12 and fed them weekly, by adding the appropriate number of Daphnia to each tray and briefly stirring the tray contents. Plants slated to receive no prey were treated identically to plants offered prey.

Treatment Trays 1-6 had to be moved several times from one growth facility to another. In addition, my initial feeding method (modelled after Sorenson and Jackson, 1968) proved to be too stressful for the fragile plants. Hence, I did not use data from plants in these trays in statistical tests.

Algal growth in all 12 trays was problematic, and when necessary, I changed nutrient solutions entirely.
and scrubbed trays. I also removed algae by floating paper towelling on the solution surface and discarding the towelling with adhered algae. The solution of some trays was filtered with a fish aquarium system.

After four weeks of growth, I terminated the experiment and took measurements as I did in the Common Garden Experiment. I did not weigh individual plants, but recorded wet and dry weights for each treatment tray. I divided the tray dry weights by the number of experimental plants per tray to estimate individual plant weight, and divided that weight into the tray mean for bladders per plant to calculate bladders per gm.

Nine weeks after Treatments 7-12 were begun, I removed McWenneneger's Slough and Tykeson Pond turions from refrigeration and put them under high temperatures to break dormancy. After about one week, I used these sprouts for Treatments 13-24 in Figure 5. I used eight Tykeson sprouts per tray for Treatments 13-18, and nine McWenneneger's sprouts per tray for Treatments 19-24.
After four weeks, I ended this portion of the experiment and recorded data as described in the Common Garden Experiment. I again computed summary statistics and drew boxplots for the variables.

I used Trays 7-12 and 19-24 to compare differences in season of turion germination as well as nutrient solution and feeding treatment differences. I used Trays 13-24 to compare the effects of collection site and treatments, in effect, a second, more complex common garden experiment. The four key variables I chose for MANOVA were the same as for the Common Garden Experiment, except that I did not use bladders per gm since I did not have weights for individual plants. Instead I used bladders per leaflet. I ran MANOVA on Treatment Trays 7-24 for the four variables, and on the ranks for these variables, and plotted profiles using tray means where interactions between factors were indicated.

For the trays acting as a common garden experiment, I expected variables to have high, medium, or low values
as described in the Common Garden Experiment section.

For trays used to examine effects of nutrient solution strength and feeding regime, I expected turions grown in one-tenth strength solution to develop as plants from nutrient-poor sites: short leaflets, intermediate numbers of bladders per leaflet and leaflet pairs per cm, and many bladders per cm. For turions grown in full strength nutrient solution, I expected long leaflets, intermediate numbers of bladders per leaflet and leaflet pairs per cm, and few bladders per cm. I expected increasing prey availability to increase growth, but not to change the relative extent of the indicator variables, as explained in the Summer Field Collection section.

I calculated the chi-square statistic for presence or absence of new turions in Trays 1-24, as well as Cramer's V and the contingency coefficient. Since a majority of the cells had expected frequencies less than five, I also calculated the lambda statistic.

In this study, I intended for light, temperature and
photoperiod conditions to be identical for all treatment trays. However, due to the necessity of using several controlled environment facilities, conditions were not identical, and the extent of fluctuation varied also. The variation between treatment conditions confounds interpretation of experimental results.
Chapter Six

Results

I. Summer Field Collection

Utricularia vulgaris plants from the six sites had definite differences in growth forms and size. The effect of site of origin was significant at $p = 0.000$ for each of the four key variables: bladders (or positions) per leaflet, leaflet pairs per cm, bladders per plant, and bladders per cm. Summarized results of the multivariate analysis of variance, and of the MANOVA on the ranked variables, are shown in Table 1.

Summary statistics for the variables measured are shown in Tables A1-A3, and boxplots for each variable, Figures A1-A7, show the extent of variation between and within sites (Appendix A). The complete MANOVA results are also given in Appendix A, in Tables A4 and A5.

II. Growth under Laboratory Conditions
The *Utricularia vulgaris* plants did not grow particularly well under laboratory conditions. Treatment trays and aquaria were susceptible to algal infections (mostly *Chlamydomonas* and *Euglena* types), which seemed to increase fragmentation in the plants. Some trays developed unidentified fungal and/or rotifer or small invertebrate scums. Growth periods longer than four weeks were desirable, but plant health was prohibitive.

Growth forms varied from long, delicate, hair-like leaves to stunted, flatter, thicker, coarser leaves along the same stem. Shoots grew from the tips of turion leaves as well as in one to several directions from the old stem axis. Plant color varied from light to dark green, with McWenneger's Slough plants darker than those from Tykeson Pond and East Bay. McWenneger's plants were also more massive and more mucilaginous than plants from the other sites.

Bladders originated on all plants but did not persist and did not develop to maturity in many cases. The
degree of algal infection seemed positively correlated to bladder abscission, as Sorenson and Jackson (1968) noted.

Leaves that had been part of the turions extended and were clearly distinguishable from newly developed leaves. These old turion leaves did possess some bladders. The old turion end of many plants darkened and decayed into fragile, slimy pieces.

Germination of collected turions was quicker in January than in November. Plants from all three collecting locations formed new turions during the experimental period.

III. Common Garden Experiment

When grown under common conditions, the *Utricularia vulgaris* plants from East Bay and McWenneger's Slough showed differences in morphology similar to those observed in mature plants collected from the field. For some of the variables measured, differences seemed to be increased or reduced relative to differences observed in
field-collected plants, but this was not tested statistically.

Summarized results from parametric and nonparametric MANOVA on the four key variables (leaflet length, bladders per cm, leaflet pairs per cm and bladders per gm) are shown in Table 2. There were no significant differences between the two replicate experiments for any of the variables, while the effect of collection site was significant for all variables in parametric and nonparametric tests except bladders per cm. In addition, a significant interaction occurred between the site and replicate factors, which confounds the magnitude of the site effect. The interaction was only important (i.e. intersecting rather than off-parallel profiles) for the bladders per cm variable. The profile plot for this interaction is shown in Figure B12 (Appendix B).

According to the ranked MANOVA, the interaction was also fairly important for the variables leaves per cm and bladders per gm (0.05 < p < 0.10).
For the one categorical variable measured, presence or absence of new tarions, there was no relationship between site of origin and development of tarions when replicates for each site were analyzed together. When the four sets of plants were examined separately, the chi-square value was significant, and the other statistics of association supported this. Statistics for this variable are given in Table 3.

Summary statistics for variables for each site are given in Tables B1-B4 (Appendix B). Boxplots for these variables, Figures B1-B11 (Appendix B), display the extent of variation between sites and between replicates of the experiment. Tables B5-B10 in Appendix B show the complete MANOVA results.

The correlation between wet and dry final weights for each plant was 0.89.

IV. Diet Experiment

In the Diet Experiment, the greatest differences in
measurements were due to plants originating from different sites. Like the mature plants collected from the field, plants grown from turions from Tykeson Pond were smaller in leaflet length, and had fewer bladders per leaflet, but had more leaflet pairs and bladders per cm than the McWenneneger's Slough turions (bladders per cm was not significantly different in field plants; Tables C1-C3, Figs. C2, C3, C6, C8, Appendix C). Again the degree of difference between sites seemed to change for lab-grown plants relative to field-collected plants.

The site effect was statistically significant, as summarized parametric and nonparametric MANOVA results show for Trays 13-18 (Tykeson Pond) and Trays 19-24 (McWenneneger's Slough; Table 4). An interaction occurred between feeding regime and collection site for these 12 treatment trays, but was only important for the bladders per cm variable in the full strength solution treatment. The profile plot for this interaction is
shown in Figure C9 (Appendix C). For the other three key variables, all the interaction profiles showed only slight departures from parallel, as may be seen on the boxplots (Figs. C2, C3, and C6, Appendix C).

For plants grown from turions collected only from McWeneger's Slough, bladders per leaflet and per cm differed significantly between experimental seasons. Feeding regime and nutrient solution strength did not have statistically significant effects on any of the variables used as indicators of growth and PCT development. Summarized results of parametric and nonparametric MANOVA for Treatment Trays 7-12 and 19-24 are shown in Table 5.

The experimental season factor interacted with the feeding regime factor, and with the solution strength factor. These interactions were important, as the profile plots show (Figs. C10 and C11, Appendix C). Solution strength and feeding regime also interacted (Fig. C12), more so in the winter than in the fall.
experimental period.

For the categorical variable, presence or absence of new turions, there was a significant correlation with season of turion germination. New turions were rarely formed in the fall, but were common in the winter treatments. Counts, chi-square and related statistics, and the lambda value are given in Tables 6 and 7.

Summary statistics for all 24 trays are given in Tables C1-C4, and boxplots for each variable are shown in Figures C1-C8 (Appendix C). Final weights per tray are shown in Table C5; wet and dry weights correlated well: $r = 0.98$. 
Table 1. Significance of Collection Site on Morphological Characters in *U. vulgaris* Plants Collected in Summer*

Significance of Univariate F Statistic

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Bladders per leaflet</th>
<th>Leaflet pairs per cm</th>
<th>Bladders per plant</th>
<th>Bladders per cm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Factor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collection Site</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
</tr>
</tbody>
</table>

*Summary of Tables A4 and A5, Appendix A*
Table 2. Significance of Collection Site, Replicate Experiment, and the Interaction between These, on Morphological Characters in *U. vulgaris* Plants Raised from Turions in a Common Garden Experiment*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Leaflet length in cm</th>
<th>Leaflet pairs per cm</th>
<th>Bladders per cm</th>
<th>Bladders per gm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collection Site</td>
<td>0.033</td>
<td>0.001</td>
<td>0.637</td>
<td>0.011</td>
</tr>
<tr>
<td></td>
<td>(0.023)</td>
<td>(0.000)</td>
<td>(0.557)</td>
<td>(0.020)</td>
</tr>
<tr>
<td>Replicate Experiment</td>
<td>Not significant in multivariate analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site-Replicate Interaction</td>
<td>0.813</td>
<td>0.229</td>
<td>0.000</td>
<td>0.238</td>
</tr>
<tr>
<td></td>
<td>(0.761)</td>
<td>(0.085)</td>
<td>(0.000)</td>
<td>(0.066)</td>
</tr>
</tbody>
</table>

*Summary of Tables B5-B10, Appendix B*
Table 3. Influence of Collection Site and Replicate Experiment on Formation of New Turions by U. vulgaris Plants Raised from Turions in a Common Garden Experiment

<table>
<thead>
<tr>
<th>Pond</th>
<th>Replicate</th>
<th>New Turions</th>
<th>Count</th>
<th>Expected Value</th>
<th>Column %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Absent</td>
<td>Present</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pond</td>
<td></td>
<td>East Bay</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pond</td>
<td></td>
<td>McWenneneger's</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pond</td>
<td></td>
<td>For replicate experiments separately/together:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pond</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Chi-square 26.69/1.70
Degrees of freedom 3/ 1
Significance level 0.00/0.19
Cramer's V (Phi) 0.76/0.18
Contingency coefficient 0.61/0.18
Lambda 0.62/0.00
Table 4. Significance of Collection Site, Nutrient Solution Strength, Feeding Regime, and Interactions between these Factors, on Morphological Characters in U. vulgaris Plants Raised from Turions in a Diet Experiment*

Significance of Univariate F Statistic

<table>
<thead>
<tr>
<th>Variable</th>
<th>Leaflet length per cm</th>
<th>Bladders per leaflet</th>
<th>Leaflet pairs per cm</th>
<th>Bladders per cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collection Site</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Site</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Feeding Regime</td>
<td>0.080</td>
<td>0.370</td>
<td>0.002</td>
<td>0.040</td>
</tr>
<tr>
<td>Regime</td>
<td>(0.177)</td>
<td>(0.124)</td>
<td>(0.049)</td>
<td>(0.096)</td>
</tr>
<tr>
<td>Solution Strength</td>
<td>Not significant in multivariate analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site-Feeding</td>
<td>0.375</td>
<td>0.067</td>
<td>0.031</td>
<td>0.011</td>
</tr>
<tr>
<td>Feeding</td>
<td>(0.501)</td>
<td>(0.184)</td>
<td>(0.459)</td>
<td>(0.026)</td>
</tr>
<tr>
<td>Site-Solution</td>
<td>Not significant in multivariate analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feeding-Solution</td>
<td>Not significant in multivariate analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site-Solution-Feeding</td>
<td>Not significant in multivariate analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Based on Trays 13-24; Summary of Tables C6-C19, Appendix C

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Table 5. Significance of Experimental Season, Nutrient Solution Strength, Feeding Regime, and Interactions between these Factors, on Morphological Characters in *U. vulgaris* Plants Raised from Turions in a Diet Experiment*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Leaflet length in cm</th>
<th>Bladders per leaflet</th>
<th>Leaflet pairs per cm</th>
<th>Bladders per cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet Bladders</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Factor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental Season</td>
<td>0.163 (0.135)</td>
<td>0.000 (0.000)</td>
<td>0.847 (0.823)</td>
<td>0.022 (0.051)</td>
</tr>
<tr>
<td>Feeding Regime</td>
<td>Not significant in multivariate analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solution Strength</td>
<td>0.111 (0.055)</td>
<td>0.198 (0.198)</td>
<td>0.994 (0.994)</td>
<td></td>
</tr>
<tr>
<td><strong>Interaction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Season-Feeding</td>
<td>0.842 (0.892)</td>
<td>0.001 (0.000)</td>
<td>0.625 (0.538)</td>
<td>0.626 (0.619)</td>
</tr>
<tr>
<td>Season-Solution</td>
<td>0.720 (0.707)</td>
<td>0.338 (0.275)</td>
<td>0.001 (0.000)</td>
<td>0.030 (0.003)</td>
</tr>
<tr>
<td>Feeding-Solution</td>
<td>0.553 (0.553)</td>
<td>0.031 (0.031)</td>
<td>0.266 (0.266)</td>
<td>0.387 (0.387)</td>
</tr>
<tr>
<td><strong>Note</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| *Based on Trays 7-12 and 19-24; Summary of Tables C20-C33, Appendix C*
Table 6. Influence of Nutrient Solution and Feeding Treatments on Formation of New Turions by *U. vulgaris* Plants Raised from Turions in a Diet Experiment

<table>
<thead>
<tr>
<th>Count</th>
<th>Tray**</th>
<th>Expected Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Column %</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>New turions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>absent</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>7.8</td>
<td>5.4</td>
</tr>
<tr>
<td></td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>present</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>5.2</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>absent</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>6.0</td>
<td>7.8</td>
</tr>
<tr>
<td></td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>present</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>4.0</td>
<td>5.2</td>
</tr>
<tr>
<td></td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

*Based on no association between new turion formation and treatment tray*

**These treatments were conducted during the fall experimental season; complete treatment details are given in Fig. 5.
Table 6. Influence of Nutrient Solution and Feeding Treatments on Formation of New Turions by *U. vulgaris* Plants Raised from Turions in a Diet Experiment (cont'd.)

<table>
<thead>
<tr>
<th>Count</th>
<th>Tray**</th>
<th>Expected Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Column %</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>New turions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>absent</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2.4</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>present</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>1.6</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>absent</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>4.8</td>
<td>6.6</td>
</tr>
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<td></td>
<td>75.0%</td>
<td>18.2%</td>
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</tr>
<tr>
<td></td>
<td>3.2</td>
<td>4.4</td>
</tr>
<tr>
<td></td>
<td>25.0%</td>
<td>81.8%</td>
</tr>
</tbody>
</table>

*Based on no association between new turion formation and treatment tray
**These treatments were conducted during the winter experimental season; complete treatment details are given in Fig. 5.
Table 7. Statistics Showing the Association between Formation of New Turions and Treatments for *U. vulgaris* Plants Raised from Turions in a Diet Experiment

<table>
<thead>
<tr>
<th>Measure</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chi-square</td>
<td>167.99</td>
</tr>
<tr>
<td>Degrees of freedom</td>
<td>23</td>
</tr>
<tr>
<td>Significance level</td>
<td>0.00</td>
</tr>
<tr>
<td>Cramer's V</td>
<td>0.86</td>
</tr>
<tr>
<td>Contingency coefficient</td>
<td>0.65</td>
</tr>
<tr>
<td>Lambda</td>
<td>0.77</td>
</tr>
</tbody>
</table>

*Based on all Trays*
Chapter Seven

Discussion

I. Summer Field Collection

As Tables A1-A3 and Figures A1-A7 (Appendix A) show, individual variation in plant measurements within sites was often large; indeed, morphological variation along individual plants was extensive in all three experiments. The samples for these measurements were not random or large, accounting for much of the non-normal distribution patterns. However, the multiple analysis of variance and the MANOVA on ranks (Table 1) both show that the pond in which Utricularia vulgaris plants grew had a significant effect on their size and development, and on PCT allocation based on four indices.

However, PCT indices (leaflet length, bladders per leaflet, leaflet pairs per cm, bladders per cm) were not significantly different between all sites; sites whose plants exhibit similar morphologies probably possess
similar nutrient availabilities. For example, plants collected from East Bay did not differ significantly from McWenneneger's Slough plants for bladders per leaflet, bladders per cm, or leaflet pairs per cm. Nutrients are probably almost as available in the Bay as they are in the Slough. Bladders per plant did differ between the two sites—no doubt a reflection of the greater length of the Slough plants.

The significant site effect revealed by the MANOVA is, of course, expected: better conditions induce more growth than do poor conditions. Not having extensive water quality data, I cannot definitively rank the six sites by trophic status. One-time water chemistry measurements and vascular hydrophyte species composition (Schuyler, 1987, pers. comm.) suggest that McWenneneger's Slough is by far the richest site. As expected, McWenneneger's plants were the largest and most vigorous, exhibiting the highest values for bladders per leaflet and bladders per plant. Having a high number of bladders
per leaflet can lead to a high number of bladders per plant, but plants which increase their number of leaflets per unit length, or dissection of leaflets, also increase total bladder number.

McWenneneger's plants did not have the greatest values for the other two variables used as indicators of growth and PCT allocation---leaflet pairs per cm, and bladders per cm. The higher values for these variables were found in plants from sites thought to be more nutrient-poor, based on water chemistry and hydrophyte diversity (Schuyler, 1987, pers. comm.; Wetzel, 1983). The higher values indicate a shunt of resources towards PCT, since increased bladders per cm values are not as linked to good growth as bladders per plant values are, as explained in Materials and Methods. Increased leaflet pairs per cm could also indicate an allocation of resources towards PCT, but that shunt is confounded by the other roles of leaflets.

Leaflet pairs per cm and bladders per cm were highest
at sites thought to be least fertile—Tykeson Pond and "Tykeson's Kettle". Tykeson Pond is dystrophic, and nutrients may well be unavailable. "Tykeson's Kettle" seemed to be mesotrophic, but it may be that the abundant *Lemna* plants take up most of the available nutrients as well as much of the incident light.

PCT levels can probably be adjusted in different ways, by adding leaflet pairs, by adding bladders per leaflet, or both. Pond chemistry and light availability may influence which of these strategies plants will follow, in accordance with allowable strategies dictated by genotype.

Since high PCT levels can be achieved in several ways, I cannot differentiate nutrient-rich sites from nutrient-poor ones based on my limited data. The rich site plants may not be allocating any extra resources to PCT, but their growth pattern forms bladders as it forms leaves. The poor site plants meanwhile may allocate resources to PCT, sacrificing general growth, resulting...
in small-sized plants with many leaflet pairs per cm and bladders per leaflet. Increasing the number of leaflets increases PCT as well as increasing foliar absorption and photosynthetic capabilities, so the plants may be relying on more than one strategy for survival. I would expect that rich site plants which automatically have much PCT do not depend on carnivorous inputs to the extent that plants do which specifically allocate resources to PCT development. To verify this expectation, it would be necessary to discern whether a given site's plants used the foliar or carnivorous pathway as the main nutrient input route, perhaps through the use of labelled nutrients.

Sources of error in the summer data are many, and interpretation of the meager results cannot be extensive. Measurements depended on which part of the plant was measured, whether in a young area with unextended internodes, a mature area, or a senescing portion which had already lost bladders and leaves.
Moreover, the ponds did not differ solely in nutrient availabilities, but were of different sizes and depths, so that temperatures, lengths of ice-free seasons, etc. varied greatly. For example, Tykeson Pond and East Bay turions were mature earlier in the fall than were those of McWenneneger's Slough. Certainly plant developmental stage also varied during the summer. Developmental stage and length of growing season probably have an effect on bladder number: the "leaves" of U. vulgaris may actually be branching systems (Arber, 1920; Sculthorpe, 1967), and conditions which encourage continued growth may increase the number of bladders per leaflet.

Nonetheless, trapping capacity and PCT allocation vary significantly between sites. These could be genetic differences, with each pond's population an ecotype, where characteristic genes dominate because of natural selection, where gene combinations have been fixed by genetic drift/founder effect, or where each population is clonal. On the other hand, the differences between
sites could be entirely environmental. That would mean a high degree of plasticity, not unusual for aquatic plants (Sculthorpe, 1967), but unusual for plants adapted for life in resource-poor environments (Bloom et al., 1985). Thirdly, and most likely, the differences could be due to an interaction of genetic and environmental factors. The summer data show that there is a site effect on resource allocation in *U. vulgaris*, but do not reveal the underlying cause.

II. Common Garden Experiment

A common garden experiment allows one to distinguish between effects of current environment and effects of genotypes or past environments. Within a common garden, the *Utricularia vulgaris* plants grown from turions from two sites did not grow to similar size, but retained some of their apparently site-specific traits. For example, the McWenneger's plants were larger in the turion stage, and finished the experiment with
significantly longer leaflets than the East Bay plants.

Bladders per gm and leaflet pairs per cm were also
significantly different between sites in the Common
Garden Experiment. I do not know if the variable
bladders per gm was significantly different among mature
plants collected from East Bay and McWenneneger's Slough,
because I have no weight data for the Summer Field
Collection.

Surprisingly, leaflet pairs per cm was not
significantly different between those two sites for
plants collected in the field. Perhaps with more time,
the differences seen in the lab would have disappeared,
as the East Bay plants compensated for their initial
smaller size as turions. On the other hand, differences
between East Bay and McWenneneger's Slough plants might
increase with time. If development could be followed
longer, an increasing or decreasing trend in differences
might suggest the relative importance of "parental"
environmental conditions versus current environmental
conditions in controlling morphological variables like PCT. The observation of a tendency toward change in the extent of morphological differences between plants grown from turions from the two sites suggests plants may indeed respond to current conditions.

The significant effect of site (MANOVA, Table 2) on morphology in these plants suggests that natural variation is not solely due to ambient environmental factors. Differences could be genetic, although the extent of variation within treatment cells and that between replicate experiments for plants grown from turions from the same site, seems excessive if each population is ecotypic. Or, differences could have been pre-set in the turions by the "generation" that formed the turions. Growing these plants through another "generation" would discriminate between these alternatives, since genetic differences would persist while any "parental" environment effect should disappear since the new turions would have been formed under the
common garden conditions. I did not examine the newly formed turions to any extent, so cannot say if any differences between Tykeson Pond and McWenneger's Slough turions seemed likely to persist into the next "generation".

Turion formation is, in itself, a resource sink. Variations in the tendency to produce turions, or the rapidity of formation, could affect other growth in U. vulgaris. Turion formation is induced by cold, drought, nutrient or light stresses (Maier, 1973; Winston and Gorham, 1979a); probably by light or crowding effects in this case.

As the chi-square and related statistics and the lambda value show (Table 3), turion formation was not correlated with collection site, therefore that response was probably largely controlled by current environmental conditions in the common garden. As the results of the separate replicate analysis show, however, turion formation was correlated with replicate experiment.
No plants formed new turions in the first replicate. The difference may be due to more crowded conditions in the second replicate (more plants, smaller aquaria), or to other differences in growing conditions.

The plants in the second replicate may have been more likely to produce turions and go dormant because they had recently been in the dormant stage. Moreover, these plants grew from turions which left the dormant stage less readily than the plants in Replicate 1 (the quick sprouters). Winston and Gorham (1979a) found that Utricularia vulgaris turions collected in Alberta, Canada, when the "parental" plants were senescing, were in a state of innate dormancy, from which turions induced to sprout soon reformed turions. The McWenneneger's turions were in this stage when I collected them; the East Bay and Tykeson turions had probably passed into the imposed dormancy stage since their "parental" stems were dead. Turions induced to sprout from imposed dormancy did not reform turions in Winston
and Gorham's study. Their growing conditions were probably more favorable than mine. Winston and Gorham (1979b) found dormancy to be hormonally controlled.

*U. vulgaris* plants observed in the field at Nimrod Warm Spring (Montana, Granite County, T12N R15W Sec. 14) had not formed turions in November, 1987, while plants at Tykeson Pond, East Bay, and McWenneneger's Slough had done so. The Nimrod plants also did not form turions under conditions of cold, low light, and low nutrients (tap water), although they eventually died, but under the same conditions East Bay, Tykeson, and McWenneneger's plants did form turions. Thus, the species does not seem to have an endogenous rhythm that dictates turion formation, but rather responds to various environmental cues in a manner controlled by its physiological state. Of course, the Nimrod plants could be a warm spring ecotype, where the endogenous rhythm has a different setpoint.

In any event, if turions are formed by plants of differing size and vigor, as was the case for the
McWeneger's and East Bay plants, those turions will start the next "generation" with a built-in size difference. During my experimental period, and perhaps during the relatively short growing season of many northwestern Montana bodies of water, this initial handicap may never be overcome. For example, if a "parent" plant grows in poor conditions and produces a tiny turion, that turion, even if placed in optimal conditions, may never grow as vigorously as another turion formed under better conditions but placed into a suboptimal habitat. Several "generations" of turion formation under good conditions, by plants originating from different sites, are probably necessary before the effect of vigorous "parent" plants could definitely be ruled out.

A lag effect could also be due to preconditioning. The environment that influences the "parent" plant's health and indirectly affects the turion also directly affects the early development of the turion. Bud and
seed formation are thought to be developmental stages that are particularly sensitive to preconditioning (Rowe, 1964). During turion formation and maturation, environmental conditions may induce changes that affect later gene expression. Conditions during turion maturation may also cause changes in growth factor proportions in the turion, as Gutterman, Thomas, and Heydecker (1975) found for Lactuca scariola seeds. Accordingly, even if plants from different sites had identical genotypes, preconditioning of turions could cause observable differences in morphology. The turions I collected were in different stages of maturation at different sites, as mentioned earlier, so preconditioning effects would certainly be possible in my experiments.

Furthermore, Utricularia vulgaris turions are not sexually produced propagules, but rather a perennating extension of the "parent" plant. Consequently, any acclimation a U. vulgaris plant may have undergone could be retained in the overwintering plant to be
expressed when dormancy is broken.

Therefore, morphological differences that I observed between plants from different sites in the Common Garden Experiment have several, not mutually exclusive, explanations:

1. Genetic differences, i.e. ecotypes at each site;
2. Differences in "parental" plant vigor and ability to endow turions ("parental" environment indirectly affects turion);
3. Differences in the turions' early environments ("parental" environment directly affects turion);
4. Differences in environmental conditions of "parent" plants, causing acclimation that was not lost during dieback to the turion phases.

My data do not allow me to determine which explanation, or what combination of explanations, is correct. Nonetheless, these data can be examined for agreement with my hypothesis that plants from poorer waters will develop more PCT.
Plants grown from turions from East Bay had more leaflet pairs per cm and bladders per gm than did plants grown from turions from McWenneger's Slough. This suggests that the lab-grown McWenneger's plants do not need to invest as much of their carbon supply in PCT. In the lab experiment, they may have had more nutrients than the East Bay plants to begin with, because of their larger turions, and they may have received more nutrients by foliar absorption through their longer leaflets. In the field, McWenneger's plants probably get more nutrients by foliar absorption from the water than they get from prey. The McWenneger's plants might have benefitted from developing more PCT under the common garden conditions (assuming nutrients were less available in the nutrient solution than in the field), but may not have done so due to preconditioning and acclimation effects. Again, following development for several "generations" in the common garden environment would help to clarify what is occurring.
Analyses of representative turions for starch and nutrient levels, and tissue analyses of experimental plants would allow comparison of resource allocation efficiency and success.

The interaction effect between replicate experiment and collection site for bladders per cm has a number of possible explanations. The replicates were started one week apart, had different numbers of plants (9 or 14) in slightly different-sized aquaria, and had minimally different growth regimes. A crowding effect, differences in degree of algal infection, or other factors could have caused the opposite response levels of bladders per cm in the second replicate. That other variables measured were not also affected is perplexing, but the nonparametric MANOVA (Table 2) does indicate some interaction (0.05 < p < 0.10) between site and replicate for the variables leaflet pairs per cm and bladders per gm. Neither MANOVA shows an interaction for leaflet length; some morphological characters may be more
responsive than others to conditions during development from turion to plant.

The Common Garden Experiment ignored the effect of prey on *Utricularia vulgaris*, in order to remove as many confounding factors as possible. In the field, plants from one site may respond differently to prey than plants from another site, especially if such plants differ in their allocation to PCT, as discussed in Materials and Methods. Accordingly, my results need to be field checked, and further experimentation would also enhance the tentative conclusions that I have drawn. (Part of the Diet Experiment, however, acts as a common garden experiment with prey.)

Without information on nutrient saturation levels for *Utricularia vulgaris* growth, I cannot say whether the nutrient solution used is a good, mediocre, or sub-optimal medium. Hence it is not clear if the plants were under sufficient nutrient stress to maximize their production of PCT.
III. Diet Experiment

In the Diet Experiment, plants did not respond to their treatment conditions in a statistically significant manner. Observed tendencies suggest plants may respond minimally to ambient conditions; with longer experimental periods, this response might increase. That there were interactions between treatment factors was not surprising, most organisms respond to a suite of factors in their environments so that they optimize survival, growth, development and reproduction. The interactions make the results harder to interpret; nonetheless, several trends are apparent.

Plants grown from Tykeson turions had shorter leaflets than those grown from McWenneneger's turions, when grown under common garden conditions. (I noted that field-collected Tykeson plants appeared to have shorter leaflets also, but I have no data to support this observation.) Leaflet length is related to turion size, since many leaflets are developed to primordial stages.
when the turion is formed. Having fewer nutrient/energy reserves in their small turions could also have affected leaflet length in lab-grown Tykeson plants, since leaves seem to be indeterminate systems, as mentioned earlier.

The number of bladders (or positions) per leaflet was less for plants grown from Tykeson Pond turions than for those from McWennesger's turions grown under the same conditions, as it was for field-collected plants from the two sites. Few bladders per leaflet correlates with having shorter leaflets. However, the difference between plants from the two sites was not so dramatic for this variable as for some of the others. This suggests the lab-grown Tykeson plants may compensate for shorter leaflets by increasing the degree of dissection of leaflets, which increases bladder number because primary bladders generally occur near the points of bifurcation.

Further, field-collected and lab-grown Tykeson plants had more leaflet pairs per cm than field and lab McWennesger's plants. This can be another developmental
strategy to increase trap number, provided that leaflets are highly dissected, as I noted above. However, the increase in leaflet number also increases foliar absorption potential (and the need to do this concurs with the probable nutrient-deficient state of the organism), and enhances photosynthetic capabilities. The stimulus for increasing leaflet number is not discernible from my experiment.

The higher bladders per cm values for lab-grown Tykeson plants relative to lab-grown McWenneger's plants suggest that the increase in leaflet pairs per cm was indeed due to the necessity of increasing nutrient inputs from carnivory. Perhaps the plants from large turions made at a rich site (McWenneger's) do not need the nutrient inputs from carnivory, while the plants from small turions made at a poor site (Tykeson) do. In the Summer Field Collection, bladders per cm was not significantly different between the two sites; with time the lab difference might have disappeared.
These between site differences seen in the lab experiments agree with my hypothesis of increased allocation of resources to PCT in less fertile sites. Interestingly, Tykeson Pond plants increased the number of bladders per cm with increasing feeding levels, while McWennenger's Slough plants did not. This response agrees with my assumption (see Materials and Methods) that dissolved nutrient levels regulate PCT allocation, while prey inputs affect growth. This increase also shows a response by the plants to ambient conditions.

The data from the Diet Experiment also seem to agree with my conclusions from the Common Garden Experiment, that past history of the individual plant and/or the early environment of the turion play a role in "progeny" development. Treatments 13-24 acted as a common garden experiment between plants from more disparate sites. Again the common conditions did not induce similar growth or PCT development in turions from different sites, and significant differences for morphological measurements
seen in field-collected plants were also found under lab conditions. Differences in morphology were greater for this common garden experiment, comparing Tykeson Pond with McWennenger's Slough, than for the comparison of East Bay with McWennenger's. Since East Bay seems to be more similar to McWennenger's Slough in terms of nutrient availabilities, this result was expected. As I stated in the Common Garden Experiment section, continued experimentation, perhaps including genotype studies (e.g. electrophoresis), would be necessary to determine the cause of morphological differences between U. vulgaris plants from different sites.

Looking at plants grown from turions only from McWennenger's Slough, there was a significant effect of experimental season on the variables bladders per leaflet and bladders per cm. Generally there were more bladders per leaflet in plants grown during the winter. This may be related to depletion of starch and other reserves in the turions by the plants while they remained dormant
(Maier, 1973; Winston and Gorham, 1979a.) Thus the developing plants would have a greater need to supplement nitrogen, phosphorous and other minerals by carnivory than plants grown in the fall from less depleted buds. In nature, by spring, turion reserves would be very low, and developing plants in nutrient-poor environments would probably have to develop more PCT more quickly than would plants developing from turions held only until winter and raised under laboratory conditions. The bladders per cm response also may be related to turion reserve depletion, but the interaction for this variable between experimental season and nutrient solution strength makes explanation difficult.

Nutrient solution strength and feeding regime did not, by themselves, have significant effects on any of the morphological measurements analyzed by MANOVA. Bladders per leaflet, leaflet pairs per cm, and bladders per cm were affected by interactions of these factor levels with each other and with experimental season, so
that main effects cannot be determined. Obviously, the PCT stimulation process is complicated. An effect of nutrient solution strength or feeding regime might have shown if development had been followed for a longer time, as past "generation" influences decreased.

Unlike the other three key variables, leaflet length for lab-grown plants did not vary significantly with season, prey or nutrient level. This morphological trait seems to be tied to the turion, and all turions from the same site were approximately the same size.

The development of new turions occurred more often in the winter treatment trays than in the fall ones, and more often on Tykeson Pond plants than on McWenneneger's Slough ones. This may be explained by the turion reserve drop over time, so that new plants in the winter experimental trays were more sensitive to growing conditions. Tykeson Pond turions were smaller than McWenneneger's turions, so reserve depletion may have been more serious for them.
New turion formation was not greatly correlated with feeding level or nutrient solution strength, although turion formation did seem to be more common in trays providing few dissolved nutrients. It may be that none of the experimental conditions were suitable for good growth in the plants, but rather were stressful, inducing reversion to the dormant phase. New turion formation could also be tied to hormone levels in the old turion which increase the probability of turion formation (Winston and Gorham, 1979b) and act to prevent plant growth during fleeting warm periods in winter.

Using the tray weights to compute bladders per gm gives data which support my hypothesis: Tykeson plants had many more bladders per gm than did McWenneneger's plants.

Overall, I think the variable bladders per gm is the best indicator for development of PCT stimulated by the need to increase nutrient uptake. High bladders per leaflet values can be due to good growth, without
reflecting an increasing reliance on carnivory. Any increase in trapping capacity due to increased leaflet pairs per cm is confounded with leaflet roles in photosynthesis and nutrient absorption. Bladders per cm values do standardize trapping potential, but do not show any shunting of resources from general growth to PCT development. But high bladders per gm values mark the plant that allocates resources to PCT.

Unfortunately, I have no weight data for the Summer Field Collection of *Utricularia vulgaris*, and the weight data for the Diet Experiment is not for individual plants. Thus I must mainly interpret resource allocation in these two experiments using the less appropriate indices of leaflet pairs per cm, bladders per leaflet, and bladders per cm.

I did not collect data on the occurrence of stem and secondary bladders. Yet plants from nutrient deficient habitats may boost PCT through these traps instead of, or in addition to, increasing numbers of primary
bladders. Of course, increasing the number of leaflet pairs and the degree of leaf dissection, which boosts primary bladder numbers, would also increase numbers of stem and secondary bladders.

With regard to the constraints mentioned in the Literature Review, my experimental conditions probably were not restrictive. Temperatures were equal to summer temperatures in *Utricularia vulgaris* habitats. Light availability in the lab was at least as great as in the darker-watered study sites. Carbon dioxide should have been sufficiently available, since the trays were open to diffusion, and the nutrient solution was buffered. Although *U. purpurea* was found to be unable to use bicarbonate (Moeller, 1978), *U. vulgaris* probably can. Moeller states that the aquatic vascular plants dependent on free carbon dioxide are usually rosette plants, which *U. vulgaris* is not. It is more similar to *Elodea* and *Ceratophyllum*, which do use bicarbonate (Moeller, 1978).
However, sources of error in this study were many. One such source is the problem of not being able to insure that *Daphnia* were trapped and digested rather than dying and adding to the nutrient solution. My initial feeding method would have taken care of this problem, but would also have killed the experimental plants. The loss of bladders and incomplete maturation of bladders, due to algal growth, handling, and other laboratory effects, decreases the likelihood that all or even most of the *Daphnia* were captured. Bladder abscission may also be related to nutrient availabilities: Bloom et al. (1985) noted that leaves senesce when the carbon budget becomes negative. Bladders are modified leaves, and the growing conditions may not have provided a positive budget.

Elimination of variation in temperature and light regimes would be advantageous, as would be better control of algal growth. Larger growing containers and a flow-through nutrient solution system would probably allow
the experimental period to continue for longer than four weeks (Knight, 1987, pers. comm). Larger sample sizes would improve statistical inference. Data defining nutrient and prey availabilities for each site would eliminate doubt from my assumptions regarding trophic status and the mechanism regulating resource allocation to PCT. Most importantly, related field work is necessary to validate the conclusions I have drawn.

Nevertheless, overall my data support my research hypothesis, that *Utricularia vulgaris* plants grown to maturity in waters of lower nutrient availabilities allocate more of their carbon resources to PCT development than do *U. vulgaris* plants in richer waters (based on water chemistry and hydrophyte diversity). My data also suggest that ambient conditions in which turions develop into plants exert little control over bladder production, at least during initial weeks of growth. Rather, the plants' genotypes and/or past environments (of past growing phases as well as turions'
early history) seem to exert more control over bladder production.

Carnivory, as an adaptation, allows plants to colonize areas they otherwise could not. It is reasonable that, along with the evolution of carnivory, came mechanisms to regulate the extent of its use. Carnivory apparently does not allow plants to adapt to new conditions very rapidly, which may contribute to the relative rarity of the carnivorous habit.
Summary and Conclusions

The following hypothesis was stated for the carnivorous plant *Utricularia vulgaris*: plants growing in sites relatively low in dissolved, inorganic nutrients will exhibit less vigorous growth but will allocate more resources to prey capture tissue (PCT) than plants growing in nutrient-rich sites.

Based on collections of mature plants from a series of sites thought to possess a range of nutrient levels, plants from poorer sites do exhibit less vigorous growth, while producing more bladders per cm of stem.

Based on allowing turions from these sites to develop for four weeks under common garden conditions, plants from poorer sites do exhibit less vigorous growth while producing more bladders per cm of stem and per gram of plant.

The common garden experiments also showed that allocation of resources to PCT appeared to be controlled largely by genotype and/or the environment under which the turion was formed (the field environment) rather than the environment in which the turion developed into a plant (the lab environment). Periods of development longer than four weeks might have reduced (or increased) differences in plants from different sites. Following plants over several vegetative "generations" in a common garden would be required to determine if genotype or a lagged environment effect has greatest control over PCT development.

As a consequence of the genetic/lagged environment effect, experiments exposing the developing turions to different prey levels
and inorganic nutrient levels for four weeks showed little effect of these treatments on PCT development/allocation. If PCT allocation is not solely genetically controlled, but requires several turion "generations" before plants respond to lab conditions, these treatments may eventually be found to affect PCT allocation.


Deksbakh, N.K. 1964. [Aquatic vegetation and its importance in controlling the consequences of industrial pollution]. Conserv. in the Urals. 4:63-66. (abs.)


Gutterman, Y., T.H. Thomas, and W. Heydecker. 1975. Effect on the progeny of applying different day length and hormone treatments to parent plants of Lactuca scariola. Physiol. Plant. 34:30-38.


Maier, R. 1973. Das Austreiben der Turionen von Utricularia vulgaris L. nach verschieden langen


Appendix A. Data Summaries, Complete MANOVA Results, and Boxplots for *Utricularia vulgaris* Plants Collected in Summer
Table A1. Data Summaries for Utricularia vulgaris
Plants Collected in Summer: Stem Diameter, Plant Length, and Leaflet Pairs per Plant
by Collection Site

<table>
<thead>
<tr>
<th>Collection Site</th>
<th>Stem Diameter</th>
<th>Total Length</th>
<th>Leaflet Pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in mm</td>
<td>in cm</td>
<td>per Plant</td>
</tr>
<tr>
<td>Tykeson</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>1.03</td>
<td>9.18</td>
<td>19.33</td>
</tr>
<tr>
<td>Std. Deviation</td>
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<td>Maximum</td>
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</tr>
<tr>
<td>Sample Size</td>
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<tr>
<td>Daphnia</td>
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<td>Mean</td>
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<tr>
<td>Std. Deviation</td>
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<td>Maximum</td>
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<tr>
<td>Loon</td>
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<tr>
<td>Mean</td>
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<td>10.03</td>
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<td>Std. Deviation</td>
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</tr>
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<td>Sample Size</td>
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<tr>
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<td>Mean</td>
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<td>Sample Size</td>
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Table A1. Data Summaries for Utricularia vulgaris
Plants Collected in Summer: Stem Diameter, Plant Length, and Leaflet Pairs per Plant by Collection Site (cont'd.)

<table>
<thead>
<tr>
<th>Collection Site</th>
<th>Stem Diameter (in mm)</th>
<th>Total Length (in cm)</th>
<th>Leaflet Pairs per Plant</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Mean</td>
<td>Std. Deviation</td>
</tr>
<tr>
<td>McWenneser's</td>
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<td></td>
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</table>

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Table A2. Data Summaries for *Ulrichia vulgaris*
Plants Collected in Summer: Leaflet Pairs per cm, Bladders/Positions per Leaflet, and Bladders/Positions per Plant by Collection Site

<table>
<thead>
<tr>
<th>Collection Site</th>
<th>Leaflet Pairs per cm</th>
<th>Bladders/Positions per Leaflet</th>
<th>Total Bladders/Positions per Plant</th>
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<tbody>
<tr>
<td>Tykeson</td>
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<tr>
<td>Mean</td>
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<td>Daphnia</td>
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<tr>
<td>Mean</td>
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<tr>
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<tr>
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<td>Mean</td>
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Table A2. Data Summaries for Utricularia vulgaris Plants Collected in Summer: Leaflet Pairs per cm, Bladders/Positions per Leaflet, and Bladders/Positions per Plant by Collection Site (cont’d.)

<table>
<thead>
<tr>
<th>Collection Site</th>
<th>Leaflet Pairs per cm</th>
<th>Bladders/Positions per Leaflet</th>
<th>Total Bladders/Positions per Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>McWennesger's</td>
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<td></td>
<td></td>
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<tr>
<td>Mean</td>
<td>1.18</td>
<td>15.24</td>
<td>1480.83</td>
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<tr>
<td>Std. Deviation</td>
<td>.06</td>
<td>1.16</td>
<td>294.14</td>
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<tr>
<td>Minimum</td>
<td>1.11</td>
<td>13</td>
<td>1017</td>
</tr>
<tr>
<td>Maximum</td>
<td>1.26</td>
<td>16</td>
<td>1936</td>
</tr>
<tr>
<td>Sample Size</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

TOTAL

| Mean            | 1.69                 | 11.22                           | 804.20                            |
| Std. Deviation  | .54                  | 3.02                            | 531.46                            |
| Minimum         | 1.05                 | 6                               | 158                               |
| Maximum         | 2.73                 | 16                              | 1936                              |
| Sample Size     | 28                   | 28                              | 28                                |

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Table A3. Data Summaries for Utricularia vulgaris
Plants Collected in Summer: Bladders/Positions per cm by Collection Site

<table>
<thead>
<tr>
<th>Collection Site</th>
<th>Bladders/Positions per cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tykeson</td>
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<tr>
<td>Mean</td>
<td>36.79</td>
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<tr>
<td>Std. Deviation</td>
<td>6.59</td>
</tr>
<tr>
<td>Minimum</td>
<td>29.63</td>
</tr>
<tr>
<td>Maximum</td>
<td>48.42</td>
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<td>Sample Size</td>
<td>6</td>
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<tr>
<td>Daphnia</td>
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</tr>
<tr>
<td>Mean</td>
<td>27.07</td>
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<td>Std. Deviation</td>
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<tr>
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<td>Maximum</td>
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<tr>
<td>Sample Size</td>
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<tr>
<td>Loon</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>29.65</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>8.42</td>
</tr>
<tr>
<td>Minimum</td>
<td>21.05</td>
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<td>Maximum</td>
<td>37.87</td>
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<td>East Bay</td>
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<td>Mean</td>
<td>28.65</td>
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<tr>
<td>Std. Deviation</td>
<td>5.56</td>
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<tr>
<td>Minimum</td>
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<tr>
<td>Maximum</td>
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<tr>
<td>Kettle</td>
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</tr>
<tr>
<td>Mean</td>
<td>50.64</td>
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<tr>
<td>Std. Deviation</td>
<td>4.22</td>
</tr>
<tr>
<td>Minimum</td>
<td>43.38</td>
</tr>
<tr>
<td>Maximum</td>
<td>54.22</td>
</tr>
<tr>
<td>Sample Size</td>
<td>5</td>
</tr>
</tbody>
</table>
Table A3. Data Summaries for Utricularia vulgaris
Plants Collected in Summer: Bladders/Positions per cm by Collection Site (cont'd.)

<table>
<thead>
<tr>
<th>Collection Site</th>
<th>Bladders/Positions per cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>McWenneser's</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>36.16</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>3.98</td>
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<tr>
<td>Minimum</td>
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<tr>
<td>Maximum</td>
<td>40.76</td>
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<tr>
<td>Sample Size</td>
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</tr>
<tr>
<td>TOTAL</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>35.81</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>9.33</td>
</tr>
<tr>
<td>Minimum</td>
<td>21.05</td>
</tr>
<tr>
<td>Maximum</td>
<td>54.22</td>
</tr>
<tr>
<td>Sample Size</td>
<td>28</td>
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</tbody>
</table>
Table A4. Parametric MANOVA Showing the Effect of Collection Site on Four Variables (Bladders/Positions per Leaflet, Bladders/Positions per Plant, Bladders/Positions per cm, Leaflet Pairs per cm) Measured on Utricularia vulgaris Plants Collected in Summer

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Approx. F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillais</td>
<td>2.39620</td>
<td>6.57394</td>
<td>20.00</td>
<td>88.00</td>
<td>.000</td>
</tr>
<tr>
<td>Hotellings</td>
<td>21.11353</td>
<td>18.47434</td>
<td>20.00</td>
<td>70.00</td>
<td>.000</td>
</tr>
<tr>
<td>Wilks</td>
<td>.00421</td>
<td>13.44509</td>
<td>20.00</td>
<td>63.97</td>
<td>.000</td>
</tr>
<tr>
<td>Roy's</td>
<td>.92798</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Univariate F-tests with (5,22) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bladders per leaflet</td>
<td>194.99891</td>
<td>51.78811</td>
<td>38.99978</td>
<td>2.35401</td>
<td>16.56742</td>
<td>.000</td>
</tr>
<tr>
<td>Bladders per cm</td>
<td>730.99787</td>
<td>621.79472</td>
<td>346.19957</td>
<td>28.26340</td>
<td>12.24904</td>
<td>.000</td>
</tr>
<tr>
<td>Bladders per plant</td>
<td>6680333.38</td>
<td>945878.094</td>
<td>1336066.68</td>
<td>42994.4588</td>
<td>31.07532</td>
<td>.000</td>
</tr>
<tr>
<td>Leaflet pairs per cm</td>
<td>6.78723</td>
<td>1.22813</td>
<td>1.35745</td>
<td>.05582</td>
<td>24.31653</td>
<td>.000</td>
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</tbody>
</table>
Table A5. Nonparametric MANOVA Showing the Effect of Collection Site on Four Variables (Bladders/Positions per Leaflet, Bladders/Positions per Plant, Bladders/Positions per cm, Leaflet Pairs per cm) Measured on *Utricularia vulgaris* Plants Collected in Summer

Multivariate Tests of Significance (*S* = 4, *M* = 0, *N* = 8 1/2)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
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<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of <em>F</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillais</td>
<td>2.27355</td>
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<td>20.00</td>
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<td>.000</td>
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<tr>
<td>Wilks</td>
<td>.00986</td>
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<td>20.00</td>
<td>63.97</td>
<td>.000</td>
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<tr>
<td>Roy's</td>
<td>.87018</td>
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Univariate *F*-tests with (5,22) D. F.

<table>
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<th>Hypoth. MS</th>
<th>Error MS</th>
<th><em>F</em></th>
<th>Sig. of <em>F</em></th>
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<tbody>
<tr>
<td>Bladders per leaflet</td>
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<td>17.39545</td>
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<td>Bladders per plant</td>
<td>1531.71667</td>
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<td>306.34333</td>
<td>13.42197</td>
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<tr>
<td>Leaflet pairs per cm</td>
<td>1501.63333</td>
<td>325.36667</td>
<td>300.32667</td>
<td>14.78939</td>
<td>20.30689</td>
<td>.000</td>
</tr>
</tbody>
</table>
Figure A1. Boxplots for Ulcinaria vulgaris Plants Collected in Summer: Stem Diameter by Collection Site

**KEY**

- * Median
- X High/Low
- O Outlier
- E Extreme

---

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**Figure A2.** Boxplots for Utricularia vulgaris Plants Collected in Summer: Bladders/Positions per Leaflet by Collection Site

- **16**
- **KEY**
- * Median
- - 25%, 75%
- X High/Low
- O Outlier
- E Extreme

---

**Site** | **T** | **D** | **L** | **E** | **K** | **M**
---|---|---|---|---|---|---

---

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Figure A3. Boxplots for Utricularia vulgaris Plants Collected in Summer: Length of Plant or Piece by Collection Site

47.50

KEY

* Median

- 25%, 75%

X High/Low

O Outlier

E Extreme

cm

+-----+
X
3
I

5.60

X

Site
T
D
L
E
K
M

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Figure A4. Boxplots for Utricularia vulgaris Plants Collected in Summer: Leaflet Pairs per Plant by Collection Site

<table>
<thead>
<tr>
<th>Site</th>
<th>T</th>
<th>D</th>
<th>L</th>
<th>E</th>
<th>K</th>
<th>M</th>
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<tbody>
<tr>
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<td></td>
</tr>
<tr>
<td>* Median</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
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<tr>
<td>- 25%, 75%</td>
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<td></td>
<td></td>
<td>X</td>
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<tr>
<td>X High/Low</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O Outlier</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>E Extreme</td>
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<td></td>
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</tr>
</tbody>
</table>

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Figure AS. Boxplots for Utricularia vulgaris Plants Collected in Summer: Leaflet Pairs per cm by Collection Site

2.73

X

KEY

---

* Median

- 25%, 75%

% High/Low

O Outlier

E Extreme

1.05

---

Site T D L E K M
Figure A6. Boxplots for Utricularia vulgaris Plants Collected in Summer: Bladders/Positions per Plant by Collection Site

<table>
<thead>
<tr>
<th>Site</th>
<th>T</th>
<th>D</th>
<th>L</th>
<th>E</th>
<th>K</th>
<th>M</th>
</tr>
</thead>
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<td>* Median</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 25%, 75%</td>
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<tr>
<td>X High/Low</td>
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</tr>
<tr>
<td>O Outlier</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E Extreme</td>
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</tr>
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<tr>
<td>E</td>
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<td></td>
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<td></td>
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</tbody>
</table>
Figure A7. Boxplots for *Utricularia vulgaris* Plants Collected in Summer: Bladders/Positions per cm by Collection Site

54.22

<table>
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</table>

KEY

<table>
<thead>
<tr>
<th>* Median</th>
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</table>

<table>
<thead>
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<th>- 25%, 75%</th>
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</thead>
</table>

<table>
<thead>
<tr>
<th>X High/Low</th>
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</thead>
</table>

<table>
<thead>
<tr>
<th>O Outlier</th>
</tr>
</thead>
</table>

| E Extreme |

<table>
<thead>
<tr>
<th>+-----</th>
</tr>
</thead>
</table>

| 21.05 |

| +----- |

<table>
<thead>
<tr>
<th>Site</th>
</tr>
</thead>
</table>

| T | D | L | E | K | M |

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Appendix B. Data Summaries, Complete MANOVA Results, Boxplots, and Profile Plots for *Utricularia vulgaris* Plants Raised from Turions in a Common Garden Experiment
Table B1. Data Summaries for Utricularia vulgaris
Plants Raised from Turions in a Common Garden Experiment: Stem Diameter, Leaflet Length and Plant Length by Collection Site and Replicate

<table>
<thead>
<tr>
<th>Site</th>
<th>Replicate</th>
<th>Stem Diameter in mm</th>
<th>Leaflet Length in cm</th>
<th>Total Length in cm</th>
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</thead>
<tbody>
<tr>
<td>East Bay</td>
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<td>1.96</td>
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<td></td>
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<td>.13</td>
<td>.45</td>
<td>13.12</td>
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<td></td>
<td></td>
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<td>.88</td>
<td>2.78</td>
<td>51.20</td>
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Table B1. Data Summaries for Utricularia vulgaris Plants Raised from Turions in a Common Garden Experiment: Stem Diameter, Leaflet Length and Plant Length by Collection Site and Replicate (cont'd.)

<table>
<thead>
<tr>
<th>Site Replicate</th>
<th>Stem Diameter in mm</th>
<th>Leaflet Length in cm</th>
<th>Total Length in cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL</td>
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</tr>
<tr>
<td>Mean</td>
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<td>28.41</td>
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<td>12.35</td>
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<td>1.11</td>
<td>7.20</td>
</tr>
<tr>
<td>Maximum</td>
<td>1.27</td>
<td>3.10</td>
<td>60.80</td>
</tr>
<tr>
<td>Sample Size</td>
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<td>46</td>
<td>48</td>
</tr>
</tbody>
</table>

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Table B2. Data Summaries for Utricularia vulgaris
Plants Raised from Turions in a Common Garden
Experiment: Leaflet Pairs per Plant, Leaflet
Pairs per cm, and Bladders/Positions per
Leaflet by Collection Site and Replicate

<table>
<thead>
<tr>
<th>Site</th>
<th>Leaflet Pairs per Plant</th>
<th>Leaflet Pairs per cm</th>
<th>Bladders/Positions per Leaflet</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Mean</td>
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<td>10.16</td>
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<td>53.84</td>
<td>.47</td>
<td>1.15</td>
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<tr>
<td>Minimum</td>
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<td>3.74</td>
<td>7.96</td>
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<td>Std. Deviation</td>
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<td>.66</td>
<td>1.31</td>
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<tr>
<td>Minimum</td>
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<td>2.95</td>
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<td>Maximum</td>
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<td><strong>McWennesner's</strong></td>
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<td>Maximum</td>
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<td><strong>McWennesner's</strong></td>
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<td>11.35</td>
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Table B2. Data Summaries for Utricularia vulgaris Plants Raised from Turions in a Common Garden Experiment: Leaflet Pairs per Plant, Leaflet Pairs per cm, and Bladders/Positions per Leaflet by Collection Site and Replicate (cont’d.)

<table>
<thead>
<tr>
<th>Site Replicate</th>
<th>Leaflet Pairs per Plant</th>
<th>Leaflet Pairs per cm</th>
<th>Bladders/Positions per Leaflet</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL</td>
<td>89.79</td>
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<tr>
<td>Mean</td>
<td>39.65</td>
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<tr>
<td>Std. Deviation</td>
<td>24.65</td>
<td>5.16</td>
<td>6</td>
</tr>
<tr>
<td>Minimum</td>
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<tr>
<td>Sample Size</td>
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<td>48</td>
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</tbody>
</table>

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Table B3. Data Summaries for *Utricularia vulgaris*
Plants Raised from Turions in a Common Garden Experiment: Bladders/Positions per Plant, Bladders/Positions per cm, and Bladders/Positions per sm by Collection Site and Replicate

<table>
<thead>
<tr>
<th>Site</th>
<th>Total Bladders/Positions per Plant</th>
<th>Bladders/Positions per cm</th>
<th>Bladders/Positions per sm Dry Weight</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
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<tr>
<td><strong>McWennenzer's</strong></td>
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Table B3. Data Summaries for *Utricularia vulgaris*
Plants Raised from Turions in a Common Garden
Experiment: Bladders/Positions per Plant,
Bladders/Positions per cm, and Bladders/
Positions per sm by Collection Site and
Replicate (cont'd.)

<table>
<thead>
<tr>
<th>Site</th>
<th>Replicate</th>
<th>Total Bladders/Positions per Plant</th>
<th>Bladders/Positions per cm</th>
<th>Bladders/Positions per sm</th>
<th>Dry Weight</th>
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Table B4. Data Summaries for Utricularia vulgaris
Plants Raised from Turions in a Common Garden Experiment: Final Wet and Dry Weights by Collection Site and Replicate

<table>
<thead>
<tr>
<th>Site</th>
<th>Blotted Weight in gm</th>
<th>Final Dry Weight in gm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std. Deviation</td>
</tr>
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<td>East Bay</td>
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<td></td>
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<tr>
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<td>2.644</td>
<td>1.610</td>
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<tr>
<td></td>
<td>.253</td>
<td>.138</td>
</tr>
<tr>
<td>East Bay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.610</td>
<td>1.199</td>
</tr>
<tr>
<td></td>
<td>.193</td>
<td>.140</td>
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<tr>
<td>McWenneser's</td>
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<tr>
<td>McWenneser's</td>
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</table>
Table B4. Data Summaries for Utricularia vulgaris Plants Raised From Turions in a Common Garden Experiment: Final Wet and Dry Weights by Collection Site and Replicate (cont'd.)

<table>
<thead>
<tr>
<th>Site Replicate</th>
<th>Blotted Weight in gm</th>
<th>Final Dry Weight in gm</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL</td>
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<tr>
<td>Mean</td>
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<td>.82</td>
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<tr>
<td>Sample Size</td>
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<td>51</td>
</tr>
</tbody>
</table>

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Table B5. Parametric MANOVA Showing the Effect of Collection Site on Four Variables (Leaflet Length, Leaflet Pairs per cm, Bladders/Positions per cm, Bladders/Positions per sm) Measured on U. vulgaris Plants Raised From Turions in a Common Garden Experiment

Multivariate Tests of Significance (S = 1, M = 1, N = 18 1/2)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Exact F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillais</td>
<td>.38487</td>
<td>6.10042</td>
<td>4.00</td>
<td>39.00</td>
<td>.001</td>
</tr>
<tr>
<td>Hotelling</td>
<td>.62568</td>
<td>6.10042</td>
<td>4.00</td>
<td>39.00</td>
<td>.001</td>
</tr>
<tr>
<td>Wilks</td>
<td>.61513</td>
<td>6.10042</td>
<td>4.00</td>
<td>39.00</td>
<td>.001</td>
</tr>
<tr>
<td>Roy's</td>
<td>.38487</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: F statistics are exact.

Univariate F-tests with (1,42) D.F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet Length</td>
<td>.78372</td>
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<td>.78372</td>
<td>.16193</td>
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<tr>
<td>Leaflet Pairs per cm</td>
<td>5.27800</td>
<td>16.72252</td>
<td>5.27800</td>
<td>.39816</td>
<td>13.25612</td>
<td>.001</td>
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<td>Bladders per cm</td>
<td>22.83592</td>
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<td>22.83592</td>
<td>101.00745</td>
<td>.22808</td>
<td>.537</td>
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<tr>
<td>Bladders per sm</td>
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<td>975634277</td>
<td>166280190</td>
<td>23229387.6</td>
<td>7.15818</td>
<td>.011</td>
</tr>
</tbody>
</table>

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Table B6. Parametric MANOVA Showing the Effect of Replicate on Four Variables (Leaflet Length, Leaflet Pairs per cm, Bladders/Positions per cm, Bladders/Positions per cm) Measured on _U. vulgaris_ Plants Raised from Turions in a Common Garden Experiment

Multivariate Tests of Significance ($S = 1, M = 1, N = 18 1/2$)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Exact F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillais</td>
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<td>4.00</td>
<td>39.00</td>
<td>.151</td>
</tr>
<tr>
<td>Hotellings</td>
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<td>1.78661</td>
<td>4.00</td>
<td>39.00</td>
<td>.151</td>
</tr>
<tr>
<td>Wilks</td>
<td>.84514</td>
<td>1.78661</td>
<td>4.00</td>
<td>39.00</td>
<td>.151</td>
</tr>
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<td>Roy's</td>
<td>.15486</td>
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</tbody>
</table>

Note: F statistics are exact.

Univariate F-tests with (1, 42) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet length</td>
<td>.86997</td>
<td>6.80126</td>
<td>.86997</td>
<td>.16193</td>
<td>5.37233</td>
<td>.025</td>
</tr>
<tr>
<td>Leaflet pairs per cm</td>
<td>.52260</td>
<td>16.72252</td>
<td>.52260</td>
<td>.39816</td>
<td>1.31256</td>
<td>.258</td>
</tr>
<tr>
<td>Bladders per cm</td>
<td>47.68313</td>
<td>4242.31304</td>
<td>47.68313</td>
<td>101.00745</td>
<td>.47208</td>
<td>.496</td>
</tr>
<tr>
<td>Bladders per cm</td>
<td>998820.692</td>
<td>975634277</td>
<td>998820.692</td>
<td>23229387.6</td>
<td>.04300</td>
<td>.837</td>
</tr>
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</table>
Table B7. Parametric MANOVA Showing the Effect of the Interaction Between Collection Site and Replicate on Four Variables (Leaflet Length, Leaflet Pairs per cm, Bladders/Positions per cm, Bladders/Positions per sm) Measured on U. vulgaris Plants Raised from Turions in a Common Garden Experiment

Multivariate Tests of Significance (S = 1, M = 1 , N = 18 1/2)

<table>
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<th>Exact F Hypoth. DF</th>
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<th>Sis. of F</th>
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</thead>
<tbody>
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<td>.36898</td>
<td>5.70116</td>
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</tr>
<tr>
<td>Hotellings</td>
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<td>5.70116</td>
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<tr>
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<td>.63102</td>
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<tr>
<td>R Owens</td>
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Note: F statistics are exact.

Univariate F-tests with (1,42) D. F.

<table>
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<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sis. of F</th>
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</thead>
<tbody>
<tr>
<td>Leaflet length</td>
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<td>6.80126</td>
<td>.00914</td>
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<td>Leaflet pairs per cm</td>
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<td>16.72252</td>
<td>.59246</td>
<td>.39816</td>
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<td>Bladders per cm</td>
<td>1672.76537</td>
<td>4242.31304</td>
<td>1672.76537</td>
<td>101.00745</td>
<td>16.56081</td>
<td>.000</td>
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<tr>
<td>Bladders per sm</td>
<td>33246863.9</td>
<td>975634277</td>
<td>33246863.9</td>
<td>23229387.6</td>
<td>1.43124</td>
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Table B8. Nonparametric MANOVA Showing the Effect of Collection Site on Four Variables (Leaflet Length, Leaflet Pairs per cm, Bladders/Positions per cm, Bladders/Positions per sm) for U. vulgaris Plants Raised from Turions in a Common Garden Experiment

Multivariate Tests of Significance (S = 1, M = 1, N = 18 1/2)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Exact F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sis. of F</th>
</tr>
</thead>
<tbody>
<tr>
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<td>11.37275</td>
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<td>39.00</td>
<td>.000</td>
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<tr>
<td>Hotellings</td>
<td>1.16644</td>
<td>11.37275</td>
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<td>.000</td>
</tr>
<tr>
<td>Wilks</td>
<td>.46159</td>
<td>11.37275</td>
<td>4.00</td>
<td>39.00</td>
<td>.000</td>
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<tr>
<td>Roy's</td>
<td>.53841</td>
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</table>

Note: F statistics are exact.

Univariate F-tests with (1,42) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
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<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sis. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet Length</td>
<td>883.44107</td>
<td>6679.51827</td>
<td>883.44107</td>
<td>159.03615</td>
<td>5.55497</td>
<td>.023</td>
</tr>
<tr>
<td>Leaflet Pairs per cm</td>
<td>2661.97843</td>
<td>5286.78721</td>
<td>2661.97843</td>
<td>125.87589</td>
<td>21.14764</td>
<td>.000</td>
</tr>
<tr>
<td>Bladders per cm</td>
<td>46.81903</td>
<td>5606.92541</td>
<td>46.81903</td>
<td>133.49822</td>
<td>.35071</td>
<td>.557</td>
</tr>
<tr>
<td>Bladders per sm</td>
<td>918.26210</td>
<td>6538.78520</td>
<td>918.26210</td>
<td>155.68536</td>
<td>5.89819</td>
<td>.020</td>
</tr>
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</table>
Table B9. Nonparametric MANOVA Showing the Effect of Replicate on Four Variables (Leaflet Length, Leaflet Pairs per cm, Bladders/Positions per cm, Bladders/Positions per sm) for U. vulgaris Plants Raised from Turions in a Common Garden Experiment

Multivariate Tests of Significance (S = 1, M = 1, N = 18 1/2)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
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<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sis. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillais</td>
<td>.15355</td>
<td>1.76874</td>
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<td>39.00</td>
<td>.155</td>
</tr>
<tr>
<td>Hotellings</td>
<td>.18141</td>
<td>1.76874</td>
<td>4.00</td>
<td>39.00</td>
<td>.155</td>
</tr>
<tr>
<td>Wilks</td>
<td>.84645</td>
<td>1.76874</td>
<td>4.00</td>
<td>39.00</td>
<td>.155</td>
</tr>
<tr>
<td>Roys</td>
<td>.15355</td>
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</tbody>
</table>

Note. F statistics are exact.

Univariate F-tests with (1, 42) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sis. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet Length</td>
<td>601.74177</td>
<td>6679.51827</td>
<td>601.74177</td>
<td>159.03615</td>
<td>3.78368</td>
<td>.058</td>
</tr>
<tr>
<td>Leaflet Pairs per cm</td>
<td>93.89712</td>
<td>5286.78721</td>
<td>93.89712</td>
<td>125.87589</td>
<td>.74595</td>
<td>.393</td>
</tr>
<tr>
<td>Bladders per cm</td>
<td>93.21797</td>
<td>5606.92541</td>
<td>93.21797</td>
<td>133.49822</td>
<td>.69827</td>
<td>.408</td>
</tr>
<tr>
<td>Bladders per sm</td>
<td>349.35138</td>
<td>6538.78520</td>
<td>349.35138</td>
<td>155.68536</td>
<td>2.24396</td>
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</table>

Note: F statistics are exact.
Table B10. Nonparametric MANOVA Showing the Effect of the Interaction Between Collection Site and Replicate on Four Variables (Leaflet Length, Leaflet Pairs per cm, Bladders/Positions per cm, Bladders/Positions per sm) for U. vulgaris Plants Raised from Turions in a Common Garden Experiment

Multivariate Tests of Significance ($S = 1$, $M = 1$, $N = 18 1/2$)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Exact $F$</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sis. of $F$</th>
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</thead>
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<td>5.92173</td>
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<td>Roy's</td>
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</tbody>
</table>

Note. F statistics are exact.

Univariate $F$-tests with (1,42) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>$F$</th>
<th>Sis. of $F$</th>
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<tr>
<td>Leaflet Length</td>
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<td>6679.51827</td>
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<tr>
<td>Leaflet Pairs per cm</td>
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<td>392.13011</td>
<td>125.87589</td>
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<tr>
<td>Bladders per cm</td>
<td>2647.41644</td>
<td>5606.92541</td>
<td>2647.41644</td>
<td>133.49822</td>
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</tr>
<tr>
<td>Bladders per sm</td>
<td>555.75562</td>
<td>6538.78520</td>
<td>555.75562</td>
<td>155.68536</td>
<td>3.56974</td>
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</table>
Figure B1. Boxplots for Utricularia vulgaris Plants Raised from Turions in a Common Garden Experiment: Stem Diameter by Collection Site and Replicate

<table>
<thead>
<tr>
<th>Site</th>
<th>E</th>
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<th>M</th>
<th>M</th>
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</thead>
<tbody>
<tr>
<td>Replicate</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
Figure B3. Boxplots for Uticaria vulgaris Plants Raised from Turions in a Common Garden Experiment: Bladders/Positions per Leaflet by Collection Site and Replicate

13

<table>
<thead>
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<th>KEY</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Median</td>
</tr>
<tr>
<td>- 25%, 75%</td>
</tr>
<tr>
<td>X High/Low</td>
</tr>
<tr>
<td>O Outlier</td>
</tr>
<tr>
<td>E Extreme</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site</th>
<th>E</th>
<th>E</th>
<th>M</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replicate</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
Figure B4. Boxplots for Ulvulularia vulgaris Plants Raised from Turions in a Common Garden Experiment: Length of Plant by Collection Site and Replicate

60.80 | O

KEY
- ----- | X
* Median | |
- 25%, 75% | |
X High/Low | ++++
O Outlier | | | E | X
E Extreme | | | ++++

cm
| | | | |
| | | * | |
| | | + | * |
| | | + | |
| | |
| |
| +++++ |
| +++++ |
| +++++ |
| |
| |
| |

7.60 | X

<table>
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<th>M</th>
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<tbody>
<tr>
<td>Replicate</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
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</tbody>
</table>
Figure B5. Boxplots for Utricularia vulgaris Plants Raised from Turions in a Common Garden Experiment: Leaflet Pairs per Plant by Collection Site and Replicate

219 | X
| |
KEY |
---------- |
* Median | X
- 25%, 75% | |
X High/Low | |
O Outlier | ++++
E Extreme | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
24 | X

---

Site E E M M
Replicate 1 2 1 2
Figure B6. Boxplots for Utricularia vulgaris Plants Raised from Turions in a Common Garden Experiment: Leaflet Pairs per cm by Collection Site and Replicate

5.38

<p>| | |</p>
<table>
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<tr>
<th></th>
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</thead>
<tbody>
<tr>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>* Median</td>
<td></td>
</tr>
<tr>
<td>- 25%, 75%</td>
<td></td>
</tr>
<tr>
<td>X High/Low</td>
<td>X X</td>
</tr>
<tr>
<td>O Outlier</td>
<td></td>
</tr>
<tr>
<td>E Extreme</td>
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2.16

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<td>1</td>
<td>2</td>
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</tbody>
</table>
Figure B7. Boxplots for *Utricularia vulgaris* Plants Raised from Turions in a Common Garden Experiment: Bladders/Positions per Plant by Collection Site and Replicate

<table>
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<th>M</th>
<th>M</th>
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</thead>
<tbody>
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<td>Replicate</td>
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<td>1</td>
<td>2</td>
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</table>
Figure 88. Boxplots for Utricularia vulgaris Plants Raised from Turions in a Common Garden Experiment: Bladders/Positions per cm by Collection Site and Replicate

<table>
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<tr>
<th>Site</th>
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<th>E</th>
<th>M</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replicate</td>
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<td>2</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
Figure B9. Boxplots for Utricularia vulgaris Plants Raised from Turions in a Common Garden Experiment: Bladders/Positions per am by Collection Site and Replicate

28790.70  |  E

KEY

--------  |  E
* Median  |  E
- 25%, 75% |  E
X High/Low |  E
O Outlier  |  E
E Extreme  |  E

am

| +++++ |
|      |
|      |
|      |
|      |
|      |

3005.80  |  E

<table>
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<th>M</th>
<th>M</th>
</tr>
</thead>
<tbody>
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<td>2</td>
<td>1</td>
<td>2</td>
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Figure B10. Boxplots for Utricularia vulgaris Plants Raised from Turions in a Common Garden Experiment: Final Wet (Blotted) Weight by Collection Site and Replicate

7.370

<table>
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</thead>
</table>

KEY

---

O Median

- 25%, 75%

X High/Low

O Outlier

E Extreme

<table>
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<tr>
<th>X</th>
<th>O</th>
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</table>

<table>
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<tr>
<th>+++++</th>
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</table>

<table>
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<thead>
<tr>
<th>+++++</th>
<th>+++++</th>
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</table>

<table>
<thead>
<tr>
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<th>+++++</th>
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</thead>
</table>

<table>
<thead>
<tr>
<th>+++++</th>
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</table>

<table>
<thead>
<tr>
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<th>X</th>
</tr>
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</table>

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Site  E  E  M  M
Replicate  1  2  1  2
Figure 8.11. Boxplots for Utricularia vulgaris Plants Raised from Turions in a Common Garden Experiment: Final Dry Weight by Collection Site and Replicate.

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<tbody>
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<td>-</td>
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<tr>
<td>25%, 75%</td>
<td></td>
</tr>
<tr>
<td>X High/Low</td>
<td></td>
</tr>
<tr>
<td>O Outlier</td>
<td>X</td>
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<tr>
<td>E Extreme</td>
<td></td>
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<tr>
<td>3m</td>
<td>++++</td>
</tr>
<tr>
<td></td>
<td>*</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>0.040</td>
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</tbody>
</table>

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Site  E  E  M  M
Replicate  1  2  1  2
Figure B12. Profile Plot for the Interaction of Collection Site and Replicate Experiment on Bladders per cm for U. vulgaris Plants Raised from Turions in a Common Garden Experiment

Key:
East Bay — — —
McWenneneger's Slough ————

bladders per cm

Replicate Experiment

1 2
Appendix C. Data Summaries, Complete MANOVA Results, Boxplots, and Profile Plots for *Utricularia vulgaris* Plants Raised from Turions in a Diet Experiment
<table>
<thead>
<tr>
<th>Treatment Tray</th>
<th>Stem Diameter</th>
<th>Leaflet Length</th>
<th>Total Length</th>
</tr>
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<tbody>
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<td></td>
<td>in mm</td>
<td>in cm</td>
<td>in cm</td>
</tr>
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<td>1.95</td>
<td>16.95</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>.11</td>
<td>.48</td>
<td>15.07</td>
</tr>
<tr>
<td>Minimum</td>
<td>.76</td>
<td>1.46</td>
<td>6.30</td>
</tr>
<tr>
<td>Maximum</td>
<td>1.13</td>
<td>2.99</td>
<td>64.90</td>
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<td>2 Mean</td>
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<td>2.13</td>
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Table C1. Data Summaries for Utricularia vulgaris
Plants Raised from Turions in a Diet
Experiment: Stem Diameter, Leaflet Length, and Plant Length by Treatment Tray (cont’d.)

| Treatment Tray | Stem Diameter | Leaflet Length | Total Length |
|               | in mm         | in cm          | in cm        |
| 6             | Mean          |  .84           | 1.93         | 21.60 |
|               | Std. Deviation|  .17           |  .44         |  9.65 |
|               | Minimum       |  .53           |  1.10        | 10.20 |
|               | Maximum       | 1.03           | 2.37         | 46.10 |
|               | Sample Size   | 13             | 13           | 13    |
| 7             | Mean          |  .88           | 1.99         | 42.75 |
|               | Std. Deviation|  .19           |  .29         | 19.56 |
|               | Minimum       |  .64           | 1.55         | 20.80 |
|               | Maximum       | 1.24           | 2.40         | 71.40 |
|               | Sample Size   | 10             | 10           | 10    |
| 8             | Mean          |  .81           | 2.00         | 32.22 |
|               | Std. Deviation|  .15           |  .22         | 12.00 |
|               | Minimum       |  .60           | 1.71         | 16.10 |
|               | Maximum       | 1.10           | 2.46         | 59.50 |
|               | Sample Size   | 13             | 12           | 13    |
| 9             | Mean          |  .84           | 2.09         | 38.31 |
|               | Std. Deviation|  .13           |  .28         | 15.21 |
|               | Minimum       |  .62           | 1.59         | 16.20 |
|               | Maximum       | 1.02           | 2.40         | 63.60 |
|               | Sample Size   | 12             | 12           | 12    |
| 10            | Mean          |  .71           | 1.87         | 37.43 |
|               | Std. Deviation|  .11           |  .36         | 19.70 |
|               | Minimum       |  .53           | 1.44         | 16.00 |
|               | Maximum       |  .84           | 2.41         | 68.60 |
|               | Sample Size   | 9              | 9            | 9     |
Table Cl. Data Summaries for Utricularia vulgaris
Plants Raised from Turions in a Diet
Experiment: Stem Diameter, Leaflet Length, and Plant Length by Treatment Tray (cont’d.)

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Table C1. Data Summaries for *Utricularia vulgaris*
Plants Raised from Turions in a Diet
Experiment: Stem Diameter, Leaflet Length, and Plant Length by Treatment Tray (cont'd.)

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Table C2. Data Summaries for *Utricularia vulgaris* Plants Raised from Turions in a Diet Experiment: Leaflet Pairs per Plant, Leaflet Pairs per cm, and Bladders/Positions per Leaflet by Treatment Tray

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Table C2. Data Summaries for Utricularia vulgaris
Plants Raised from Turions in a Diet
Experiment: Leaflet Pairs per Plant, Leaflet
Pairs per cm, and Bladders/Positions per
Leaflet by Treatment Tray (cont’d.)

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Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
Table C2. Data Summaries for Utricularia vulgaris
Plants Raised from Turions in a Diet
Experiment: Leaflet Pairs per Plant, Leaflet
Pairs per cm, and Bladders/Positions per
Leaflet by Treatment Tray (cont’d.)

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Table C2. Data Summaries for *Utricularia vulgaris*
Plants Raised from Jurions in a Diet Experiment: Leaflet Pairs per Plant, Leaflet Pairs per cm, and Bladders/Positions per Leaflet by Treatment Tray (cont’d.)

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Table C2. Data Summaries for Utricularia vulgaris Plants Raised from Turions in a Diet Experiment: Leaflet Pairs per Plant, Leaflet Pairs per cm, and Bladders/Positions per Leaflet by Treatment Tray (cont'd.)

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Table C3. Data Summaries for Utricularia vulgatris Plants Raised from Turions in a Diet Experiment: Bladders/Positions per Plant and Bladders/Positions per cm by Treatment Tray

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Table C3. Data Summaries for Utricularia vulgaris Plants Raised from Turions in a Diet Experiment: Bladders/Positions per Plant and Bladders/Positions per cm by Treatment Tray (cont’d.)

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<td>1279.76</td>
<td>14.80</td>
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<tr>
<td>Minimum</td>
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<td>4647</td>
<td>89.40</td>
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<td>Sample Size</td>
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</tbody>
</table>

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Table C3. Data Summaries for Utricularia vulgaris 
Plants Raised from Turions in a Diet 
Experiment: Bladders/Positions per Plant and 
Bladders/Positions per cm by Treatment Tray 
(cont’d.)

<table>
<thead>
<tr>
<th>Treatment Tray</th>
<th>Total Bladders/ Positions per Plant</th>
<th>Bladders/ Positions per cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
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</tr>
<tr>
<td>Mean</td>
<td>2241.75</td>
<td>67.63</td>
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<tr>
<td>Std. Deviation</td>
<td>1201.81</td>
<td>12.15</td>
</tr>
<tr>
<td>Minimum</td>
<td>1262</td>
<td>47.62</td>
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<tr>
<td>Maximum</td>
<td>4672</td>
<td>84.12</td>
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<td>Sample Size</td>
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<tr>
<td>Mean</td>
<td>2655.17</td>
<td>73.45</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>1815.74</td>
<td>11.48</td>
</tr>
<tr>
<td>Minimum</td>
<td>1124</td>
<td>55.27</td>
</tr>
<tr>
<td>Maximum</td>
<td>6926</td>
<td>91.44</td>
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<td>Sample Size</td>
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<tr>
<td>Mean</td>
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<td>74.92</td>
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<tr>
<td>Std. Deviation</td>
<td>393.74</td>
<td>30.88</td>
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<td>Minimum</td>
<td>705</td>
<td>50.19</td>
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<td>Maximum</td>
<td>1601</td>
<td>119.44</td>
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<td>Mean</td>
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<td>Std. Deviation</td>
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<td>Mean</td>
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<td>113.08</td>
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<tr>
<td>Std. Deviation</td>
<td>744.54</td>
<td>26.90</td>
</tr>
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<td>Minimum</td>
<td>710</td>
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<td>Maximum</td>
<td>2878</td>
<td>147.34</td>
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<tr>
<td>Sample Size</td>
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<td>6</td>
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</tbody>
</table>
Table C3. Data Summaries for *Utricularia vulgaris*
Plants raised from Turions in a Diet Experiment: Bladders/Positions per Plant and Bladders/Positions per cm by Treatment Tray
(cont'd.)

<table>
<thead>
<tr>
<th>Treatment Tray</th>
<th>Total Bladders/Positions per Plant</th>
<th>Bladders/Positions per cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>1900.21</td>
<td>82.34</td>
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<tr>
<td>Std. Deviation</td>
<td>1065.90</td>
<td>7.24</td>
</tr>
<tr>
<td>Minimum</td>
<td>1081</td>
<td>70.00</td>
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<td>Maximum</td>
<td>4477</td>
<td>91.56</td>
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<td>Sample Size</td>
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<td>10</td>
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<tr>
<td>17</td>
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<td></td>
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<tr>
<td>Mean</td>
<td>1659.66</td>
<td>92.26</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>1015.78</td>
<td>14.33</td>
</tr>
<tr>
<td>Minimum</td>
<td>668</td>
<td>68.12</td>
</tr>
<tr>
<td>Maximum</td>
<td>3410</td>
<td>115.81</td>
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<td>Sample Size</td>
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<tr>
<td>Mean</td>
<td>919.03</td>
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<tr>
<td>Std. Deviation</td>
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<td>Minimum</td>
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<td>Maximum</td>
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</tr>
<tr>
<td>Std. Deviation</td>
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<td>24.22</td>
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<tr>
<td>Minimum</td>
<td>733</td>
<td>46.67</td>
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<td>Maximum</td>
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<tr>
<td>20</td>
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<td></td>
</tr>
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<td>Mean</td>
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<td>Std. Deviation</td>
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<td>16.36</td>
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<tr>
<td>Minimum</td>
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<td>52.21</td>
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<td>Maximum</td>
<td>2352</td>
<td>95.42</td>
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<tr>
<td>Sample Size</td>
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</tbody>
</table>
Table C3. Data Summaries for Utricularia vulgaris Plants Raised from Turions in a Diet Experiment: Bladders/Positions per Plant and Bladders/Positions per cm by Treatment Tray (cont’d.)

<table>
<thead>
<tr>
<th>Treatment Tray</th>
<th>Total Bladders/Positions per Plant</th>
<th>Bladders/Positions per cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>1788.75</td>
<td>74.00</td>
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<tr>
<td>Std. Deviation</td>
<td>457.69</td>
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<tr>
<td>Minimum</td>
<td>1107</td>
<td>49.96</td>
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<tr>
<td>Maximum</td>
<td>2559</td>
<td>86.22</td>
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<td>Sample Size</td>
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<td>11</td>
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<tr>
<td>22</td>
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<td></td>
</tr>
<tr>
<td>Mean</td>
<td>2214.69</td>
<td>66.55</td>
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<td>Std. Deviation</td>
<td>679.81</td>
<td>12.62</td>
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<tr>
<td>Minimum</td>
<td>1336</td>
<td>48.79</td>
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<td>Maximum</td>
<td>3332</td>
<td>90.76</td>
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<td>Mean</td>
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<td>982.60</td>
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<td>1471</td>
<td>50.34</td>
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<td>Maximum</td>
<td>4848</td>
<td>124.61</td>
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<td>Std. Deviation</td>
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<td>Maximum</td>
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<td>160.35</td>
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</table>
Table C4. Data Summaries for *Utricularia vulgaris* Plants Raised from Turions in a Diet Experiment: Bladders/Positions per gm by Treatment Tray

<table>
<thead>
<tr>
<th>Treatment Tray</th>
<th>Bladders/ Positions per gm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7478.05</td>
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<tr>
<td>2</td>
<td>6294.89</td>
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<tr>
<td>3</td>
<td>4748.21</td>
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<tr>
<td>4</td>
<td>3662.16</td>
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<tr>
<td>5</td>
<td>7140.01</td>
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<td>6</td>
<td>7575.93</td>
</tr>
<tr>
<td>7</td>
<td>9493.07</td>
</tr>
<tr>
<td>8</td>
<td>9733.42</td>
</tr>
<tr>
<td>9</td>
<td>10103.10</td>
</tr>
<tr>
<td>10</td>
<td>9700.60</td>
</tr>
<tr>
<td>11</td>
<td>12933.17</td>
</tr>
<tr>
<td>12</td>
<td>11433.75</td>
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<td>13</td>
<td>11778.63</td>
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<td>14</td>
<td>31618.65</td>
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<td>15</td>
<td>30433.69</td>
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<td>16</td>
<td>33932.32</td>
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<tr>
<td>17</td>
<td>29788.77</td>
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<td>18</td>
<td>33419.27</td>
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<tr>
<td>19</td>
<td>10963.78</td>
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<td>10008.25</td>
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<td>21</td>
<td>11642.75</td>
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<td>22</td>
<td>8227.95</td>
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<td>23</td>
<td>9404.55</td>
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<tr>
<td>24</td>
<td>9222.57</td>
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</tbody>
</table>

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Table C5. Data Summaries for Utricularia vulgaris Plants Raised from Turions in a Diet Experiment: Final Wet (Blotted) and Dry Weights by Treatment Tray

<table>
<thead>
<tr>
<th>Treatment Tray</th>
<th>Blotted Weight in gm</th>
<th>Final Dry Weight in gm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>34.66</td>
<td>1.93</td>
</tr>
<tr>
<td>2</td>
<td>27.20</td>
<td>1.55</td>
</tr>
<tr>
<td>3</td>
<td>38.50</td>
<td>2.24</td>
</tr>
<tr>
<td>4</td>
<td>47.97</td>
<td>2.95</td>
</tr>
<tr>
<td>5</td>
<td>56.92</td>
<td>3.32</td>
</tr>
<tr>
<td>6</td>
<td>32.12</td>
<td>2.50</td>
</tr>
<tr>
<td>7</td>
<td>54.23</td>
<td>2.90</td>
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<td>8</td>
<td>44.05</td>
<td>2.65</td>
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<td>9</td>
<td>43.48</td>
<td>2.81</td>
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<td>10</td>
<td>34.27</td>
<td>2.31</td>
</tr>
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<td>11</td>
<td>30.43</td>
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<td>4.22</td>
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<td>14</td>
<td>3.99</td>
<td>.20</td>
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<tr>
<td>15</td>
<td>4.65</td>
<td>.32</td>
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<td>16</td>
<td>10.61</td>
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<td>6.36</td>
<td>.39</td>
</tr>
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<td>3.58</td>
<td>.22</td>
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<td>19</td>
<td>22.45</td>
<td>1.10</td>
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<td>20</td>
<td>24.97</td>
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</tr>
<tr>
<td>21</td>
<td>27.16</td>
<td>1.69</td>
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</table>

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Table C5. Data Summaries for *Utricularia vulgaris*
Plants Raised from Turions in a Diet Experiment: Final Wet (Blotted) and Dry Weights by Treatment Tray (cont'd.)

<table>
<thead>
<tr>
<th>Treatment Tray</th>
<th>Blotted Weight in gm</th>
<th>Final Dry Weight in gm</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>49.09</td>
<td>3.23</td>
</tr>
<tr>
<td>23</td>
<td>40.69</td>
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<tr>
<td>24</td>
<td>32.38</td>
<td>2.23</td>
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</table>
Table C6. Parametric MANOVA Showing the Effect of Collection Site on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on *U. vulgaris* Plants Raised from Turions in a Diet Experiment

**Multivariate Tests of Significance (S = 1, M = 1, N = 45 1/2)**

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Exact F Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillais</td>
<td>0.69453</td>
<td>52.86262</td>
<td>4.00</td>
<td>93.00</td>
</tr>
<tr>
<td>Hotellings</td>
<td>2.27366</td>
<td>52.86262</td>
<td>4.00</td>
<td>93.00</td>
</tr>
<tr>
<td>Wilks</td>
<td>0.30547</td>
<td>52.86262</td>
<td>4.00</td>
<td>93.00</td>
</tr>
<tr>
<td>Roy's</td>
<td>0.69453</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note.** F statistics are exact.

**Univariate F-tests with (1,96) D. F.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet length</td>
<td>9.84522</td>
<td>8.11073</td>
<td>9.84522</td>
<td>0.08449</td>
<td>116.52973</td>
</tr>
<tr>
<td>Bladders per leaflet</td>
<td>122.43504</td>
<td>127.22390</td>
<td>122.43504</td>
<td>1.32525</td>
<td>92.38645</td>
</tr>
<tr>
<td>Leaflet pairs per cm</td>
<td>81.74156</td>
<td>68.37827</td>
<td>81.74156</td>
<td>0.71227</td>
<td>114.76145</td>
</tr>
<tr>
<td>Bladders per cm</td>
<td>9783.93945</td>
<td>37163.1876</td>
<td>9783.93945</td>
<td>387.11654</td>
<td>25.27389</td>
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</table>
### Table C7. Parametric MANOVA Showing the Effect of Feeding Regime on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

**Multivariate Tests of Significance (S = 2, N = 1/2, N = 45 1/2)**

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Approx. F Hypoth. DF</th>
<th>Error DF</th>
<th>Sis. of F</th>
</tr>
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<tbody>
<tr>
<td>Pillais</td>
<td>.15102</td>
<td>1.91941</td>
<td>8.00</td>
<td>188.00</td>
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<tr>
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<td>.17254</td>
<td>1.98422</td>
<td>8.00</td>
<td>184.00</td>
</tr>
<tr>
<td>Wilks</td>
<td>.85107</td>
<td>1.95233</td>
<td>8.00</td>
<td>186.00</td>
</tr>
<tr>
<td>Roy's</td>
<td>.13563</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note. F statistic for WILK'S Lambda is exact.*

**Univariate F-tests with (2,96) D. F.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sis. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet length</td>
<td>.43814</td>
<td>8.11073</td>
<td>.21907</td>
<td>.08449</td>
<td>2.59294</td>
<td>.080</td>
</tr>
<tr>
<td>Bladders per leaflet</td>
<td>2.66452</td>
<td>127.22390</td>
<td>1.33226</td>
<td>1.32525</td>
<td>1.00529</td>
<td>.370</td>
</tr>
<tr>
<td>Leaflet pairs per cm</td>
<td>9.11411</td>
<td>68.37827</td>
<td>4.55705</td>
<td>.71227</td>
<td>6.39790</td>
<td>.002</td>
</tr>
<tr>
<td>Bladders per cm</td>
<td>2.569.02405</td>
<td>3.7163.1876</td>
<td>1.284.51203</td>
<td>3.87.11654</td>
<td>3.31815</td>
<td>.040</td>
</tr>
</tbody>
</table>
Table C8. Parametric MANOVA Showing the Effect of Nutrient Solution Strength on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgarius Plants Raised from Turions in a Diet Experiment

Multivariate Tests of Significance (S = 1, M = 1, N = 45 1/2)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Exact F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillais</td>
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<td>.97682</td>
<td>4.00</td>
<td>93.00</td>
<td>.424</td>
</tr>
<tr>
<td>Hotellings</td>
<td>.04201</td>
<td>.97682</td>
<td>4.00</td>
<td>93.00</td>
<td>.424</td>
</tr>
<tr>
<td>Wilks</td>
<td>.95968</td>
<td>.97682</td>
<td>4.00</td>
<td>93.00</td>
<td>.424</td>
</tr>
<tr>
<td>Roy's</td>
<td>.04032</td>
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<td></td>
</tr>
</tbody>
</table>

Note: F statistics are exact.

Univariate F-tests with (1,96) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
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<td>.07844</td>
<td>8.11073</td>
<td>.07844</td>
<td>.08449</td>
<td>.92846</td>
<td>.338</td>
</tr>
<tr>
<td>Bladders per leaflet</td>
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<td>127.22390</td>
<td>.34901</td>
<td>1.32525</td>
<td>.26335</td>
<td>.609</td>
</tr>
<tr>
<td>Leaflet pairs per cm</td>
<td>2.35922</td>
<td>68.37827</td>
<td>2.35922</td>
<td>.71227</td>
<td>3.31224</td>
<td>.072</td>
</tr>
<tr>
<td>Bladders per cm</td>
<td>622.20186</td>
<td>37163.1876</td>
<td>622.20186</td>
<td>387.11654</td>
<td>1.60727</td>
<td>.208</td>
</tr>
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</table>
Table C9. Parametric MANOVA Showing the Effect of the Interaction between Collection Site and Feeding Regime on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

Multivariate Tests of Significance (S = 2, M = 1/2, N = 45 1/2)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Approx. F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillais</td>
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<td>2.95844</td>
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<td>188.00</td>
<td>.004</td>
</tr>
<tr>
<td>Hotellings</td>
<td>.27581</td>
<td>3.17181</td>
<td>8.00</td>
<td>184.00</td>
<td>.002</td>
</tr>
<tr>
<td>Wilks</td>
<td>.78054</td>
<td>3.06626</td>
<td>8.00</td>
<td>186.00</td>
<td>.003</td>
</tr>
<tr>
<td>Roy's</td>
<td>.20308</td>
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<td></td>
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</tr>
</tbody>
</table>

Note. F statistic for WILK'S Lambda is exact.

Univariate F-tests with (2,96) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet length</td>
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<td>.08379</td>
<td>.08449</td>
<td>.99174</td>
<td>.375</td>
</tr>
<tr>
<td>Bladders per leaflet</td>
<td>7.37643</td>
<td>127.22390</td>
<td>3.68822</td>
<td>1.32525</td>
<td>2.78304</td>
<td>.067</td>
</tr>
<tr>
<td>Leaflet pairs per cm</td>
<td>5.13419</td>
<td>68.37827</td>
<td>2.56709</td>
<td>.71227</td>
<td>3.60408</td>
<td>.031</td>
</tr>
<tr>
<td>Bladders per cm</td>
<td>3641.31997</td>
<td>37163.1876</td>
<td>1820.65999</td>
<td>387.11654</td>
<td>4.70313</td>
<td>.011</td>
</tr>
</tbody>
</table>
Table C10. Parametric MANOVA Showing the Effect of the Interaction between Collection Site and Nutrient Solution Strength on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

Multivariate Tests of Significance \((S = 1, M = 1, N = 45 \frac{1}{2})\)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Exact F Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillais</td>
<td>.07830</td>
<td>1.97507</td>
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<td>.105</td>
</tr>
<tr>
<td>Hotellings</td>
<td>.08495</td>
<td>1.97507</td>
<td>4.00</td>
<td>.105</td>
</tr>
<tr>
<td>Wilks</td>
<td>.92170</td>
<td>1.97507</td>
<td>4.00</td>
<td>.105</td>
</tr>
<tr>
<td>Roy's</td>
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<td>1.97507</td>
<td>4.00</td>
<td>.105</td>
</tr>
</tbody>
</table>

Note: F statistics are exact.

Univariate F-Tests with \((1,96) D. F.\)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet length</td>
<td>.36948</td>
<td>8.11073</td>
<td>.36948</td>
<td>.08449</td>
<td>4.37323</td>
<td>.039</td>
</tr>
<tr>
<td>Bladders per leaflet</td>
<td>2.53029</td>
<td>127.22390</td>
<td>2.53029</td>
<td>1.32525</td>
<td>1.90930</td>
<td>.170</td>
</tr>
<tr>
<td>Leaflet pairs per cm</td>
<td>.27918</td>
<td>68.37827</td>
<td>.27918</td>
<td>.71227</td>
<td>.39195</td>
<td>.533</td>
</tr>
<tr>
<td>Bladders per cm</td>
<td>40.92115</td>
<td>37163.1876</td>
<td>40.92115</td>
<td>387.11654</td>
<td>.10571</td>
<td>.746</td>
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</tbody>
</table>
Table C11. Parametric MANOVA Showing the Effect of the Interaction between Feeding Regime and Nutrient Solution Strength on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm). Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

Multivariate Tests of Significance ($S = 2, M = 1/2, N = 45 1/2$)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Approx. F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillais</td>
<td>0.10310</td>
<td>1.27722</td>
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<td>0.258</td>
</tr>
<tr>
<td>Hotellings</td>
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<td>1.26313</td>
<td>8.00</td>
<td>184.00</td>
<td>0.265</td>
</tr>
<tr>
<td>Wilks</td>
<td>0.89908</td>
<td>1.27025</td>
<td>8.00</td>
<td>186.00</td>
<td>0.261</td>
</tr>
<tr>
<td>Roy's</td>
<td>0.07358</td>
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<td></td>
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</tr>
</tbody>
</table>

Note. F statistic for WILK'S Lambda is exact.

Univariate F-tests with (2,96) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
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<tbody>
<tr>
<td>Leaflet length</td>
<td>4.3536</td>
<td>8.11073</td>
<td>0.21768</td>
<td>0.08449</td>
<td>2.57648</td>
<td>0.081</td>
</tr>
<tr>
<td>Bladders per leaflet</td>
<td>2.74730</td>
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<td>1.37365</td>
<td>1.32525</td>
<td>1.03652</td>
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</tr>
<tr>
<td>Leaflet pairs per cm</td>
<td>0.01300</td>
<td>68.37827</td>
<td>0.00650</td>
<td>0.71227</td>
<td>0.00912</td>
<td>0.991</td>
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<tr>
<td>Bladders per cm</td>
<td>119.60925</td>
<td>37163.1876</td>
<td>59.80462</td>
<td>387.11654</td>
<td>154.49</td>
<td>0.857</td>
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</table>
Table C12. Parametric MANOVA showing the effect of the interaction between Collection Site, Feeding Regime and Nutrient Solution Strength on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

Multivariate Tests of Significance (S = 2, M = 1/2, N = 45 1/2)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Approx. F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
</tr>
</thead>
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<tr>
<td>Pillais</td>
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<td>188.00</td>
<td>.071</td>
</tr>
<tr>
<td>Hotellings</td>
<td>1.16058</td>
<td>1.84666</td>
<td>8.00</td>
<td>184.00</td>
<td>.071</td>
</tr>
<tr>
<td>Wilks</td>
<td>1.05828</td>
<td>1.84616</td>
<td>8.00</td>
<td>186.00</td>
<td>.071</td>
</tr>
<tr>
<td>Roy</td>
<td>1.11032</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Note: F statistic for WILK'S Lambda is exact.

Univariate F-tests with (2,96) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
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<td>Bladders per leaflet</td>
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<td>0.75558</td>
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</tr>
<tr>
<td>Leaflet pairs per cm</td>
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<td>68.37827</td>
<td>1.34107</td>
<td>0.71227</td>
<td>1.88281</td>
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</tr>
<tr>
<td>Bladders per cm</td>
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<td>37163.1876</td>
<td>669.93863</td>
<td>387.11654</td>
<td>1.73059</td>
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</table>
Table C13. Nonparametric MANOVA Showing the Effect of Collection Site on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

Multivariate Tests of Significance (S = 1, M = 1, N = 45 1/2)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Exact F Hypoth. DF</th>
<th>Error DF</th>
<th>Sis. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillais</td>
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<td>70.49206</td>
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</tr>
<tr>
<td>Hotellings</td>
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<td>70.49206</td>
<td>4.00</td>
<td>93.00</td>
</tr>
<tr>
<td>Wilks</td>
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<td>70.49206</td>
<td>4.00</td>
<td>93.00</td>
</tr>
<tr>
<td>Roy's</td>
<td>.75198</td>
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</tbody>
</table>

Note: F statistics are exact.

Univariate F-tests with (1,96) D. F.

<table>
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<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sis. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet length</td>
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<td>179022.505</td>
<td>2002.18335</td>
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</tr>
<tr>
<td>Bladders per leaflet</td>
<td>239102.834</td>
<td>225969.458</td>
<td>239102.834</td>
<td>2353.84852</td>
<td>101.57953</td>
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</tr>
<tr>
<td>Leaflet pairs per cm</td>
<td>244427.693</td>
<td>222530.110</td>
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<td>2318.02197</td>
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<tr>
<td>Bladders per cm</td>
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<td>307909.663</td>
<td>89042.8961</td>
<td>3207.39232</td>
<td>27.76177</td>
<td>.000</td>
</tr>
</tbody>
</table>
Table C14. Nonparametric MANOVA Showing the Effect of Feeding Regime on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

Multivariate Tests of Significance ($S = 2$, $M = 1/2$, $N = 45, 1/2$)

<table>
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<tr>
<th>Test Name</th>
<th>Value</th>
<th>Approx. F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
</tr>
</thead>
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<tr>
<td>Pillais</td>
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<td>8.00</td>
<td>188.00</td>
<td>.000</td>
</tr>
<tr>
<td>Hotellings</td>
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<td>4.96874</td>
<td>8.00</td>
<td>184.00</td>
<td>.000</td>
</tr>
<tr>
<td>Wilks</td>
<td>.69299</td>
<td>4.67928</td>
<td>8.00</td>
<td>186.00</td>
<td>.000</td>
</tr>
<tr>
<td>Roy's</td>
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</tr>
</tbody>
</table>

*Note.* F statistic for WILK'S Lambda is exact.

Univariate F-tests with (2,96) D. F.

<table>
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<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet length</td>
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<td>192209.602</td>
<td>3529.52898</td>
<td>2002.18335</td>
<td>1.76284</td>
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</tr>
<tr>
<td>Bladders per leaflet</td>
<td>10031.0184</td>
<td>225969.458</td>
<td>5015.50918</td>
<td>2353.84852</td>
<td>2.13077</td>
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</tr>
<tr>
<td>Leaflet pairs per cm</td>
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<td>222530.110</td>
<td>7222.53251</td>
<td>2318.02197</td>
<td>3.11582</td>
<td>.049</td>
</tr>
<tr>
<td>Bladders per cm</td>
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<td>307909.663</td>
<td>7693.33174</td>
<td>3207.39232</td>
<td>2.39863</td>
<td>.096</td>
</tr>
</tbody>
</table>
Table C15. Nonparametric MANOVA Showing the Effect of Nutrient Solution Strength on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

Multivariate Tests of Significance (S = 1, M = 1 , N = 45 1/2)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Exact F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
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<td>93.00</td>
<td>.831</td>
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<tr>
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<td>4.00</td>
<td>93.00</td>
<td>.831</td>
</tr>
<tr>
<td>Wilks</td>
<td>.98444</td>
<td>.36748</td>
<td>4.00</td>
<td>93.00</td>
<td>.831</td>
</tr>
<tr>
<td>Roy's</td>
<td>.01556</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. F statistics are exact.

Univariate F-tests with (1,96) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
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<td>388.42241</td>
<td>2002.18335</td>
<td>.19400</td>
<td>.661</td>
</tr>
<tr>
<td>Bladders per leaflet</td>
<td>279.52708</td>
<td>225969.458</td>
<td>279.52708</td>
<td>2353.84852</td>
<td>.11875</td>
<td>.731</td>
</tr>
<tr>
<td>Leaflet pairs per cm</td>
<td>2748.26919</td>
<td>222530.110</td>
<td>2748.26919</td>
<td>2318.02197</td>
<td>1.10561</td>
<td>.279</td>
</tr>
<tr>
<td>Bladders per cm</td>
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<td>307909.663</td>
<td>1285.48577</td>
<td>3207.39232</td>
<td>.40079</td>
<td>.528</td>
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</table>
Table C16. Nonparametric MANOVA Showing the Effect of the Interaction between Collection Site and Feeding Regime on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. v. vulgaris Plants Raised from Turions in a Diet Experiment

Multivariate Tests of Significance (S = 2, M = 1/2, N = 45 1/2)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Approx. F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sis. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillais</td>
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<td>8.00</td>
<td>188.00</td>
<td>.002</td>
</tr>
<tr>
<td>Hotellings</td>
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<td>8.00</td>
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<td>.001</td>
</tr>
<tr>
<td>Wilks</td>
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<td>3.32637</td>
<td>8.00</td>
<td>186.00</td>
<td>.001</td>
</tr>
<tr>
<td>Roy's</td>
<td>.21114</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: F statistic for WILK'S Lambda is exact.

Univariate F-tests with (2, 96) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sis. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet length</td>
<td>2784.97734</td>
<td>192209.602</td>
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<td>.501</td>
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<tr>
<td>Bladders per leaflet</td>
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<td>4055.05979</td>
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<td>Leaflet pairs per cm</td>
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<td>222530.110</td>
<td>1821.19687</td>
<td>2318.02197</td>
<td>.78567</td>
<td>.459</td>
</tr>
<tr>
<td>Bladders per cm</td>
<td>24267.0100</td>
<td>307909.663</td>
<td>12133.5050</td>
<td>3207.39232</td>
<td>3.78298</td>
<td>.026</td>
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</table>
Table C17. Nonparametric MANOVA Showing the Effect of the Interaction between Collection Site and Nutrient Solution Strength on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgare Plants Raised from Turions in a Diet Experimen

Multivariate Tests of Significance ($S = 1$, $M = 1$, $N = 45 1/2$)

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<tr>
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<th>Error DF</th>
<th>Sig. of F</th>
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<td>93.00</td>
<td>.103</td>
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<td>Hotellings</td>
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<td>1.98589</td>
<td>4.00</td>
<td>93.00</td>
<td>.103</td>
</tr>
<tr>
<td>Wilks</td>
<td>.92131</td>
<td>1.98589</td>
<td>4.00</td>
<td>93.00</td>
<td>.103</td>
</tr>
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<td>Roy's</td>
<td>.07869</td>
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<td></td>
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</tr>
</tbody>
</table>

Note: F statistics are exact.

Univariate F-tests with $(1,96)$ D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet length</td>
<td>5432.58571</td>
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<td>.103</td>
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<tr>
<td>Bladders per leaflet</td>
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<td>225969.458</td>
<td>2489.44405</td>
<td>2353.84852</td>
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<td>Leaflet pairs per cm</td>
<td>7448.16851</td>
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<td>13277.7308</td>
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Table C18. Nonparametric MANOVA Showing the Effect of the Interaction between Feeding Regime and Nutrient Solution Strength on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

Multivariate Tests of Significance (S = 2, M = 1/2, N = 45 1/2)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Approx. F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
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<td>.500</td>
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<tr>
<td>Roy's</td>
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</tr>
</tbody>
</table>

Note. F statistic for WILK’S Lambda is exact.

Univariate F-tests with (2,96) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
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<td>Leaflet length</td>
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<td>Bladders per leaflet</td>
<td>5893.91229</td>
<td>225969.458</td>
<td>2941.95615</td>
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</tr>
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<td>Leaflet pairs per cm</td>
<td>360.13726</td>
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Table C19. Nonparametric MANOVA Showing the Effect of the Interaction between Collection Site, Feeding Regime and Nutrient Solution Strength on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgariis Plants Raised from Turions in a Diet Experiment

Multivariate Tests of Significance ($S = 2$, $M = 1/2$, $N = 45 1/2$)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
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<td>Wilks</td>
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<td>1.59419</td>
<td>8.00</td>
<td>186.00</td>
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<td>Roy's</td>
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</table>

Note: F statistic for WILK'S Lambda is exact.

Univariate F-tests with (2, 96) D. F.

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<th>Variable</th>
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<th>Hypoth. MS</th>
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<td>3207.39232</td>
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<td>.129</td>
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Table C20. Parametric MANOVA Showing the Effect of Experimental Season on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

Multivariate Tests of Significance ($S = 1$, $M = 1$, $N = 55$)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
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<th>Hypoth. DF</th>
<th>Error DF</th>
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<td>.000</td>
</tr>
<tr>
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<td>15.26282</td>
<td>4.00</td>
<td>112.00</td>
<td>.000</td>
</tr>
<tr>
<td>Wilks</td>
<td>.64721</td>
<td>15.26282</td>
<td>4.00</td>
<td>112.00</td>
<td>.000</td>
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<tr>
<td>Royals</td>
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</tbody>
</table>

Note: $F$ statistics are exact.

Univariate $F$-tests with $(1,115)$ D. F.

<table>
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<th>Variable</th>
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<th>Sig. of $F$</th>
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</tr>
<tr>
<td>Bladders per leaflet</td>
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<td>154.90420</td>
<td>26.95324</td>
<td>1.34699</td>
<td>20.00994</td>
<td>.000</td>
</tr>
<tr>
<td>Leaflet pairs per cm</td>
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<td>.01255</td>
<td>.33516</td>
<td>.03745</td>
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</tr>
<tr>
<td>Bladders per cm</td>
<td>1418.87705</td>
<td>30241.2424</td>
<td>1418.87705</td>
<td>262.96732</td>
<td>5.39564</td>
<td>.022</td>
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</tbody>
</table>
Table C21. Parametric MANOVA Showing the Effect of Feeding Regime on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

Multivariate Tests of Significance ($S = 2, M = 1/2, N = 55$)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Approx. F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
</tr>
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</tr>
<tr>
<td>Hotellings</td>
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<td>1.32034</td>
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<td>222.00</td>
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</tr>
<tr>
<td>Wilks</td>
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<td>1.32493</td>
<td>8.00</td>
<td>224.00</td>
<td>.232</td>
</tr>
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<td>Roy's</td>
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<td></td>
</tr>
</tbody>
</table>

Note: F statistic for WILK'S Lambda is exact.

Univariate F-tests with (2,115) D. F.

<table>
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<tr>
<th>Variable</th>
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<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
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<td>1.34699</td>
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<td>.09984</td>
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</tbody>
</table>

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Table C22. Parametric MANOVA Showing the Effect of Nutrient Solution Strength on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

Multivariate Tests of Significance (S = 1, M = 1, N = 55)

<table>
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<tr>
<th>Test Name</th>
<th>Value</th>
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<th>Sis. of F</th>
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<td>3.11331</td>
<td>4.00</td>
<td>112.00</td>
</tr>
<tr>
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<td>3.11331</td>
<td>4.00</td>
<td>112.00</td>
</tr>
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<td>Roy's</td>
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</table>

Note: F statistics are exact.

Univariate F-tests with (1,115) D.F.

<table>
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<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sis. of F</th>
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</tr>
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<td>Bladders per leaflet</td>
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<td>154.90420</td>
<td>5.06025</td>
<td>1.34699</td>
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<td>Leaflet pairs per cm</td>
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<td>1.67941</td>
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<td>.01279</td>
<td>262.96732</td>
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</table>
Table C23. Parametric MANOVA Showing the Effect of the Interaction between
Experimental Season and Feeding Regime on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Approx. F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
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<td>8.00</td>
<td>222.00</td>
<td>.001</td>
</tr>
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<td>3.43375</td>
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<td>.001</td>
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</table>

Note. F statistic for WILK'S Lambda is exact.

Univariate F-tests with (2,115) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet length</td>
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<td>.01531</td>
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<td>.17252</td>
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<td>Bladders per leaflet</td>
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<td>154.90420</td>
<td>9.96312</td>
<td>1.34699</td>
<td>7.39656</td>
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</tr>
<tr>
<td>Leaflet pairs per cm</td>
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<td>.33516</td>
<td>.47174</td>
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<td>30241.2424</td>
<td>123.49736</td>
<td>262.96732</td>
<td>.46963</td>
<td>.626</td>
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</table>
Table C24. Parametric MANOVA Showing the Effect of the Interaction between Experimental Season and Nutrient Solution Strength on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

Multivariate Tests of Significance (S = 1, M = 1, N = 55)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
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<th>Error DF</th>
<th>Sig. of F</th>
</tr>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: F statistics are exact.

Univariate F-tests with (1,115) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
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<td>.08875</td>
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<tr>
<td>Bladders per leaflet</td>
<td>1.24745</td>
<td>154.90420</td>
<td>1.24745</td>
<td>1.34699</td>
<td>.92610</td>
</tr>
<tr>
<td>Leaflet pairs per cm</td>
<td>3.57797</td>
<td>38.54306</td>
<td>3.57797</td>
<td>.33516</td>
<td>10.67549</td>
</tr>
<tr>
<td>Bladders per cm</td>
<td>1268.27533</td>
<td>30241.2424</td>
<td>1268.27533</td>
<td>262.96732</td>
<td>4.82294</td>
</tr>
</tbody>
</table>
Table C25. Parametric MANOVA Showing the Effect of the Interaction between Feeding Regime and Nutrient Solution Strength on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Fairs per cm, Bladders/Positions per cm) Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

Multivariate Tests of Significance (S = 2, M = 1/2, N = 55)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Approx. F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillais</td>
<td>.13441</td>
<td>2.03525</td>
<td>8.00</td>
<td>226.00</td>
<td>.043</td>
</tr>
<tr>
<td>Hotellings</td>
<td>.14615</td>
<td>2.02787</td>
<td>8.00</td>
<td>222.00</td>
<td>.044</td>
</tr>
<tr>
<td>Wilks</td>
<td>.09627</td>
<td>2.03169</td>
<td>8.00</td>
<td>224.00</td>
<td>.044</td>
</tr>
<tr>
<td>Roys</td>
<td>.00613</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: F statistic for WILK'S Lambda is exact.

Univariate F-tests with (2,115) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet length</td>
<td>.10566</td>
<td>10.20612</td>
<td>.05283</td>
<td>.08875</td>
<td>.59525</td>
<td>.553</td>
</tr>
<tr>
<td>Bladders per leaflet</td>
<td>9.65718</td>
<td>154.90420</td>
<td>4.82859</td>
<td>1.34699</td>
<td>3.58472</td>
<td>.031</td>
</tr>
<tr>
<td>Leaflet pairs per cm</td>
<td>.89854</td>
<td>39.54306</td>
<td>.44927</td>
<td>.33516</td>
<td>1.34047</td>
<td>.266</td>
</tr>
<tr>
<td>Bladders per cm</td>
<td>503.60465</td>
<td>30241.2424</td>
<td>251.80233</td>
<td>262.96732</td>
<td>.95754</td>
<td>.387</td>
</tr>
</tbody>
</table>

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Table C26. Parametric MANOVA Showing the Effect of the Interaction between Experimental Season, Feeding Regime and Nutrient Solution Strength on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

Multivariate Tests of Significance (S = 2, M = 1/2, N = 55)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Approx. F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillais</td>
<td>.05641</td>
<td>.81998</td>
<td>8.00</td>
<td>226.00</td>
<td>.586</td>
</tr>
<tr>
<td>Hotellings</td>
<td>.05078</td>
<td>.81553</td>
<td>8.00</td>
<td>222.00</td>
<td>.590</td>
</tr>
<tr>
<td>Wilks</td>
<td>.94405</td>
<td>.81780</td>
<td>8.00</td>
<td>224.00</td>
<td>.588</td>
</tr>
<tr>
<td>Roys</td>
<td>.04645</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: F statistic for WILK'S Lambda is exact.

Univariate F-tests with (2,115) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet length</td>
<td>.11058</td>
<td>10.20612</td>
<td>.05529</td>
<td>.08875</td>
<td>.62298</td>
<td>.538</td>
</tr>
<tr>
<td>Bladders per leaflet</td>
<td>.07824</td>
<td>154.90420</td>
<td>.03912</td>
<td>1.34699</td>
<td>.02904</td>
<td>.971</td>
</tr>
<tr>
<td>Leaflet pairs per cm</td>
<td>.74206</td>
<td>38.54306</td>
<td>.37103</td>
<td>.33516</td>
<td>1.10704</td>
<td>.334</td>
</tr>
<tr>
<td>Bladders per cm</td>
<td>409.65818</td>
<td>30241.2424</td>
<td>204.82909</td>
<td>262.96732</td>
<td>.77891</td>
<td>.461</td>
</tr>
</tbody>
</table>
Table C27. Nonparametric MANOVA Showing the Effect of Experimental Season on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Exact F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillais</td>
<td>.31262</td>
<td>12.73419</td>
<td>4.00</td>
<td>112.00</td>
<td>.000</td>
</tr>
<tr>
<td>Hotellings</td>
<td>.45479</td>
<td>12.73419</td>
<td>4.00</td>
<td>112.00</td>
<td>.000</td>
</tr>
<tr>
<td>Wilks</td>
<td>.68738</td>
<td>12.73419</td>
<td>4.00</td>
<td>112.00</td>
<td>.000</td>
</tr>
<tr>
<td>Roy's</td>
<td>.31262</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. F statistics are exact.

Univariate F-tests with (1,115) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet length</td>
<td>5821.10819</td>
<td>294778.841</td>
<td>5821.10819</td>
<td>2563.29427</td>
<td>2.27095</td>
<td>.135</td>
</tr>
<tr>
<td>Bladders per leaflet</td>
<td>47735.3177</td>
<td>304693.706</td>
<td>47735.3177</td>
<td>2649.51049</td>
<td>18.01666</td>
<td>.000</td>
</tr>
<tr>
<td>Leaflet pairs per cm</td>
<td>115.90920</td>
<td>264484.102</td>
<td>115.90920</td>
<td>2299.86175</td>
<td>.05040</td>
<td>.823</td>
</tr>
<tr>
<td>Bladders per cm</td>
<td>12468.0631</td>
<td>367512.367</td>
<td>12468.0631</td>
<td>3195.75971</td>
<td>3.90144</td>
<td>.051</td>
</tr>
</tbody>
</table>
Table C28. Non-parametric MANOVA showing the effect of feeding regime on four variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) measured on *U. vulgaris* Plants raised from turions in a diet experiment

### Multivariate Tests of Significance (S = 2, M = 1/2, N = 55)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Approx. F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sis. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillais</td>
<td>.09404</td>
<td>1.39382</td>
<td>8.00</td>
<td>226.00</td>
<td>.200</td>
</tr>
<tr>
<td>Hotellings</td>
<td>.09932</td>
<td>1.37806</td>
<td>8.00</td>
<td>222.00</td>
<td>.207</td>
</tr>
<tr>
<td>Wilks</td>
<td>.90790</td>
<td>1.38598</td>
<td>8.00</td>
<td>224.00</td>
<td>.204</td>
</tr>
<tr>
<td>Roy</td>
<td>.06368</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: F statistic for WILK'S Lambda is exact.

### Univariate F-tests with (2,115) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sis. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet length</td>
<td>10961.8949</td>
<td>294778.841</td>
<td>5480.94747</td>
<td>2563.29427</td>
<td>2.13824</td>
<td>.123</td>
</tr>
<tr>
<td>Bladders per leaflet</td>
<td>10421.8334</td>
<td>304693.706</td>
<td>5210.91671</td>
<td>2649.51049</td>
<td>1.96675</td>
<td>.145</td>
</tr>
<tr>
<td>Leaflet Pairs per cm</td>
<td>1623.41851</td>
<td>264484.102</td>
<td>811.70925</td>
<td>2299.86175</td>
<td>.35294</td>
<td>.703</td>
</tr>
<tr>
<td>Bladders per cm</td>
<td>1835.92632</td>
<td>367512.367</td>
<td>917.96316</td>
<td>3195.75971</td>
<td>.28724</td>
<td>.751</td>
</tr>
</tbody>
</table>
Table C29. Nonparametric MANOVA Showing the Effect of Nutrient Solution Strength on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

Multivariate Tests of Significance ($S = 1$, $M = 1$, $N = 55$)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Exact F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillais</td>
<td>0.04361</td>
<td>1.27678</td>
<td>4.00</td>
<td>112.00</td>
<td>0.283</td>
</tr>
<tr>
<td>Hotellings</td>
<td>0.04560</td>
<td>1.27678</td>
<td>4.00</td>
<td>112.00</td>
<td>0.283</td>
</tr>
<tr>
<td>Wilks</td>
<td>0.95639</td>
<td>1.27678</td>
<td>4.00</td>
<td>112.00</td>
<td>0.283</td>
</tr>
<tr>
<td>Roy's</td>
<td>0.04361</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: F statistics are exact.

Univariate F-tests with (1,115) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet length</td>
<td>6436.48054</td>
<td>294773.841</td>
<td>6436.48054</td>
<td>2563.29427</td>
<td>2.51102</td>
<td>0.116</td>
</tr>
<tr>
<td>Bladders per leaflet</td>
<td>8834.16705</td>
<td>304693.706</td>
<td>8834.16705</td>
<td>2649.51049</td>
<td>3.33426</td>
<td>0.070</td>
</tr>
<tr>
<td>Leaflet pairs per cm</td>
<td>2567.24625</td>
<td>264484.102</td>
<td>2567.24625</td>
<td>2299.86175</td>
<td>1.11626</td>
<td>0.293</td>
</tr>
<tr>
<td>Bladders per cm</td>
<td>1.10440 367512.367</td>
<td>1.10440 3195.75971</td>
<td></td>
<td></td>
<td>0.00035</td>
<td>0.985</td>
</tr>
</tbody>
</table>
Table C30. Nonparametric MANOVA Showing the Effect of the Interaction between Experimental Season and Feeding Regime on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

Multivariate Tests of Significance ($S = 2$, $M = 1/2$, $N = 55$)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Approx. F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillais</td>
<td>.23314</td>
<td>3.72764</td>
<td>8.00</td>
<td>226.00</td>
<td>.000</td>
</tr>
<tr>
<td>Hotellings</td>
<td>.29999</td>
<td>4.16234</td>
<td>8.00</td>
<td>222.00</td>
<td>.000</td>
</tr>
<tr>
<td>Wilks</td>
<td>.76820</td>
<td>3.94624</td>
<td>8.00</td>
<td>224.00</td>
<td>.000</td>
</tr>
<tr>
<td>Roy's</td>
<td>.22723</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: F statistic for WILK'S Lambda is exact.

Univariate F-tests with (2,115) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet length</td>
<td>584.69410</td>
<td>294.778.841</td>
<td>292.34705</td>
<td>2563.29427</td>
<td>.11405</td>
<td>.892</td>
</tr>
<tr>
<td>Bladders per leaflet</td>
<td>43988.6505</td>
<td>304693.706</td>
<td>21994.3253</td>
<td>2649.51049</td>
<td>8.30128</td>
<td>.000</td>
</tr>
<tr>
<td>Leaflet pairs per cm</td>
<td>2866.71450</td>
<td>264484.102</td>
<td>1433.35725</td>
<td>2299.86175</td>
<td>.62324</td>
<td>.538</td>
</tr>
<tr>
<td>Bladders per cm</td>
<td>3082.24890</td>
<td>367512.367</td>
<td>1541.12445</td>
<td>3195.75971</td>
<td>.48224</td>
<td>.619</td>
</tr>
</tbody>
</table>
Table C31. Nonparametric MANOVA showing the Effect of the Interaction between Experimental Season and Nutrient Solution Strength on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

Multivariate Tests of Significance (S = 1, M = 1, N = 55)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Exact F Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
</tr>
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<tbody>
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<td>112.00</td>
</tr>
<tr>
<td>Hotellings</td>
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<td>7.55257</td>
<td>4.00</td>
<td>112.00</td>
</tr>
<tr>
<td>Wilks</td>
<td>.78757</td>
<td>7.55257</td>
<td>4.00</td>
<td>112.00</td>
</tr>
<tr>
<td>Roy's</td>
<td>.21243</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: F statistics are exact.

Univariate F-tests with (1,115) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
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<td>Leaflet length</td>
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<td>363.46444 2563.29427</td>
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<td>.707</td>
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<td></td>
</tr>
<tr>
<td>Bladders per leaflet</td>
<td>3182.39779 304693.706</td>
<td>3182.39779 2649.51049</td>
<td>1.20113</td>
<td>.275</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaflet pairs per cm</td>
<td>43182.1906 264484.102</td>
<td>43182.1906 2299.86175</td>
<td>18.77599</td>
<td>.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bladders per cm</td>
<td>28927.1869 367512.367</td>
<td>28927.1869 3195.75971</td>
<td>9.05174</td>
<td>.003</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table C32. Nonparametric MANOVA Showing the Effect of the Interaction between Feeding Regime and Nutrient Solution Strength on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

Multivariate Tests of Significance (S = 2, M = 1/2, N = 55)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Approx. F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillais</td>
<td>11367</td>
<td>1.70238</td>
<td>8.00</td>
<td>226.00</td>
<td>.099</td>
</tr>
<tr>
<td>Hotellings</td>
<td>12465</td>
<td>1.72947</td>
<td>8.00</td>
<td>222.00</td>
<td>.093</td>
</tr>
<tr>
<td>Wilks</td>
<td>88783</td>
<td>1.71617</td>
<td>8.00</td>
<td>224.00</td>
<td>.096</td>
</tr>
<tr>
<td>Roys</td>
<td>09839</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. F statistic for WILK’S Lambda is exact.

Univariate F-tests with (2,115) D. F.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet length</td>
<td>3424.44731</td>
<td>294778.841</td>
<td>1712.22365</td>
<td>2563.29427</td>
<td>.66798</td>
<td>.515</td>
</tr>
<tr>
<td>Bladders per leaflet</td>
<td>17083.2980</td>
<td>304693.706</td>
<td>8541.64901</td>
<td>2649.51049</td>
<td>3.22386</td>
<td>.043</td>
</tr>
<tr>
<td>Leaflet pairs per cm</td>
<td>5601.38492</td>
<td>264484.102</td>
<td>2800.69246</td>
<td>2299.86175</td>
<td>1.21777</td>
<td>.300</td>
</tr>
<tr>
<td>Bladders per cm</td>
<td>5897.76143</td>
<td>367512.367</td>
<td>2948.88071</td>
<td>3195.75971</td>
<td>.92275</td>
<td>.400</td>
</tr>
</tbody>
</table>
Table C33. Nonparametric MANOVA Showing the Effect of the Interaction between Experimental Season, Feeding Regime and Nutrient Solution Strength on Four Variables (Leaflet Length, Bladders/Positions per Leaflet, Leaflet Pairs per cm, Bladders/Positions per cm) Measured on U. vulgaris Plants Raised from Turions in a Diet Experiment

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Value</th>
<th>Approx. F</th>
<th>Hypoth. DF</th>
<th>Error DF</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillais</td>
<td>.05602</td>
<td>.81406</td>
<td>8.00</td>
<td>226.00</td>
<td>.591</td>
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<td>Hotellings</td>
<td>.05782</td>
<td>.80232</td>
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<td>222.00</td>
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<td>Wilks</td>
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<td>.80820</td>
<td>8.00</td>
<td>224.00</td>
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<td>Roy's</td>
<td>.03739</td>
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</table>

Note. F statistic for WILK'S Lambda is exact.

Multivariate Tests of Significance (S = 2, M = 1/2, N = 55)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypoth. SS</th>
<th>Error SS</th>
<th>Hypoth. MS</th>
<th>Error MS</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet length</td>
<td>3142.54624</td>
<td>294778.841</td>
<td>1571.27312</td>
<td>2563.29427</td>
<td>.61299</td>
<td>.543</td>
</tr>
<tr>
<td>Bladders per leaflet</td>
<td>790.58724</td>
<td>304693.706</td>
<td>395.29362</td>
<td>2649.51049</td>
<td>.14919</td>
<td>.862</td>
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<tr>
<td>Leaflet pairs per cm</td>
<td>3994.40196</td>
<td>264484.102</td>
<td>1997.20098</td>
<td>2299.86175</td>
<td>.86840</td>
<td>.422</td>
</tr>
<tr>
<td>Bladders per cm</td>
<td>2079.30169</td>
<td>367512.367</td>
<td>1039.65084</td>
<td>3195.75971</td>
<td>.32532</td>
<td>.723</td>
</tr>
</tbody>
</table>
Figure C1. Boxplots for *U. vulgaris* Plants Raised from Turions in a Diet Experiment: Stem Diameter by Treatment Tray
Figure C2. Boxplots for *U. vulgaris* Plants Raised from Turions in a Diet Experiment: Leaflet Length by Treatment Tray
Figure C3. Boxplots for U. vulgaris Plants Raised from Turions in a Diet Experiment: Bladders/Positions per Leaflet by Treatment Tray

**KEY**

- Median
- 25%, 75%
- High/Low
- Outlier
- Extreme

**SOLSTR**
1 1 1 1 1 1 1 1 1 1 1 1 2

**FEED**
1 1 1 1 2 2 2 2 3 3 3 3 1

**SEASON**
1 1 2 2 1 1 2 2 1 1 2 2 1

**TRAY**
4 11 16 22 6 12 17 23 3 10 18 24 2

**SOLSTR**
2 2 2 2 2 2 2 2 2 2 2 2

**FEED**
1 1 1 1 2 2 2 2 3 3 3 3 1

**SEASON**
1 1 2 2 1 1 2 2 1 1 2 2 1

**TRAY**
8 13 19 5 9 14 20 1 7 15 21

**Key:**

Solstr = Nutrient Solution Strength
1 = one-tenth strength
2 = full strength

Feed = Feeding Regime
1 = no prey
2 = 10 prey
3 = 100 prey

Season = Experimental Season
1 = fall
2 = winter
Figure C4. Boxplots for *U. vulgaris* Plants Raised from Turions in a Diet Experiment: Length of Plant by Treatment Tray

**KEY**
- Median
- 25% - 75%
- H: High
- M: Medium
- L: Low
- O: Outlier

**SOLSTR**
- 1: Nutrient Solution Strength
  - 1: One-tenth strength
  - 2: Full strength

**FEED**
- 1: No prey
- 2: 10 prey
- 3: 100 prey

**SEASON**
- 1: Fall
- 2: Winter

**TRAY**
- 4-20

---

See associated text for detailed explanation.
Figure C5. Boxplots for U. vulgaris Plants Raised from Turions in a Diet Experiment: Leaflet Pairs per Plant by Treatment Tray

**Key:**
- 0: Median
- 25%, 75%
- X: High/Low
- O: Outlier
- E: Extreme

### Key:
- Solstr = Nutrient Solution Strength
  - 1 = one-tenth strength
  - 2 = full strength
- Feed = Feeding Regime
  - 1 = no prey
  - 2 = 10 prey
  - 3 = 100 prey
- Season = Experimental Season
  - 1 = fall
  - 2 = winter

<table>
<thead>
<tr>
<th>Solstr</th>
<th>Feed</th>
<th>Season</th>
<th>Tray</th>
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<tr>
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</tbody>
</table>

---

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Figure C6. Boxplots for *U. vulgaris* Plants Raised from Turions in a Diet Experiment: Leaflet Pairs per cm by Treatment Tray

**KEY**

- Median
- 25%, 75%
- X High/Low
- D Outlier
- E Extreme

**SOLSTR**

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<tr>
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</thead>
</table>

**FEED**

<table>
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</table>

**SEASON**

<table>
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<th>1</th>
<th>2</th>
<th>2</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
</table>

**TRAY**

|   | 4 | 11 | 16 | 22 | 6 | 12 | 17 | 23 | 3 | 10 | 18 | 24 | 2 |

**Key:**

- SOLSTR = Nutrient Solution Strength
  - 1 = one-tenth strength
  - 2 = full strength
- Feed = Feeding Regime
  - 1 = no prey
  - 2 = 10 prey
  - 3 = 100 prey
- Season = Experimental Season
  - 1 = fall
  - 2 = winter
Figure C7. Boxplots for *U. vulgaris* Plants Raised from Turions in a Diet Experiment: Bladders/Positions per Plant by Treatment Tray

**Key:**
- Median
- 25%, 75%
- High/Low
- Outlier
- Extreme

<table>
<thead>
<tr>
<th>SOLSTR</th>
<th>FEED</th>
<th>SEASON</th>
<th>TRAY</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
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<tr>
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<td>2</td>
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</tr>
<tr>
<td>4</td>
<td>11</td>
<td>16</td>
<td>22</td>
</tr>
</tbody>
</table>

**Key:**
- Solstr = Nutrient Solution Strength
  - 1 = one-tenth strength
  - 2 = full strength
- Feed = Feeding Regime
  - 1 = no prey
  - 2 = 10 prey
  - 3 = 100 prey
- Season = Experimental Season
  - 1 = fall
  - 2 = winter
Figure C8. Boxplots for U. vulgaris Plants Raised from Turions in a Diet Experiment: Bladders/Positions per cm by Treatment Tray

**Figure C8 Details:**
- **X:** Median
- **E:** 25%, 75%
- **#:** Outlier
- **E:** Extreme

**Key:**
- **Solstr:** Nutrient Solution Strength
  - 1 = one-tenth strength
  - 2 = full strength
- **Feed:** Feeding Regime
  - 1 = no prey
  - 2 = 10 prey
  - 3 = 100 prey
- **Season:** Experimental Season
  - 1 = fall
  - 2 = winter
- **Tray:** 4, 11, 16, 22, 6, 12, 17, 23, 3, 10, 18, 24

**Data Table:**
- **Solstr:** 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 2
- **Feed:** 1, 1, 2, 2, 2, 3, 3, 3, 1
- **Season:** 1, 2, 2, 1, 1, 2, 2, 1, 2, 2, 1
- **Tray:** 4, 11, 16, 22, 6, 12, 17, 23, 3, 10, 18, 24, 2

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Figure C9. Profile Plot for the Interaction of Collection Site and Feeding Regime on Bladders per cm for *U. vulgaris* Plants Raised from Turions in a Diet Experiment

Key:

Tykeson's Pond ———
McWennenger's Slough ———

Bladders per cm

0.1 strength nutrient solution

full strength nutrient solution

*Based on Trays 13-24

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Figure C10. Profile Plot for the Interaction of Experimental Season and Feeding Regime on Key Variables for U. vulgaris Plants Raised from Turions in a Diet Experiment

Key:
- fall experimental season ---
- winter experimental season ------

Variable:

Leaflet length

Leaflet pairs per cm

Bladders per leaflet

Bladders per cm

*Based on Trays 7-12 and 19-24

*Based on Trays 7-12 and 19-24

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Figure C11. Profile Plot for the Interaction of Experimental Season and Nutrient Solution Strength on Key Variables for U. vulgaris Plants Raised from Turions in a Diet Experiment*

Key:
fall experimental season ----
winter experimental season ———

Variable: 0 10 100 Feeding Regime

Leaflet length

Leaflet pairs per cm

Bladders per leaflet

Bladders per cm

*Based on Trays 7-12 and 19-24
Figure C12. Profile Plot for the Interaction of Feeding Regime and Nutrient Solution Strength on Key Variables for U. vulgaris Plants Raised from Turions in a Diet Experiment*

Key:
0.1 strength nutrient solution ——— ——— ———
full strength nutrient solution ——— ——— ———

Variable:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Fall</th>
<th>Winter</th>
<th>Experimental Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet length</td>
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<tr>
<td>Leaflet pairs per cm</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Bladders per leaflet</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Bladders per cm</td>
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</tbody>
</table>

*Based on Trays 7-12 and 19-24

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