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The response of Liriope, Hosta, and Hedera to sunlight and fertilization

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To the Graduate Council:

I am submitting herewith a thesis written by Mei-Li Mary Wu entitled "The response of Liriope, Hosta, and Hedera to sunlight and fertilization." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant Sciences.

B. S. Pickett, Major Professor

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February 18, 1972

To the Graduate Council:

I am submitting herewith a thesis written by Mei-Li Mary Wu entitled "The Response of *Liriope*, *Hosta*, and *Hedera* to Sunlight and Fertilization." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Horticulture.

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THE RESPONSE OF *LIRIOPE*, *HOSTA*, AND *HEDERA* TO SUNLIGHT AND FERTILIZATION

A Thesis
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Mei-Li Mary Wu
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ABSTRACT

The purpose of this investigation was to study the response of three different species of ground covers, *Liriope*, *Hosta*, and *Hedera* to various degrees of shade and levels of nitrogen and potassium.

The plants were grown in pots under three light conditions: full sunlight, half of full sunlight, and a quarter of full sunlight. Two levels of nitrogen and potassium, high and low, were applied at the beginning of this experiment.

Data for this study included height, fresh and dry weights, number of leaves or shoots, chlorophyll and starch content.

Height and number of leaves of these three ground covers were significantly affected by light and nitrogen treatment. In most cases, the reduction of light and a high nitrogen level produced better growth and better appearing plants than were obtained under full sunlight and low nitrogen fertilization.

Differences due to potassium levels were usually non-significant.

TABLE OF CONTENTS

CHAPTER PAGE

I. INTRODUCTION 1

II. REVIEW OF LITERATURE 3

Ecological Requirements of Ground Covers 3

Possibilities of Modifying Ecological Situations 4

With light 4

By fertilization 6

Light and fertilization. 7

III. MATERIALS AND METHODS. 10

General Procedure. 10

Chemical analysis. 12

Soil testing 12

Chlorophyll determination. 13

Starch determination 13

IV. RESULTS AND DISCUSSION 16

Light. 16

Fertilization. 26

V. SUMMARY AND CONCLUSION 34

LITERATURE CITED. .36

VITA. 40

LIST OF TABLES

TABLE PAGE

I. Height and Number of Leaves or Shoots of *Liriope*, *Hosta*, and *Hedera* Produced under Three Light Levels. 17

II. Total Length of Shoots of *Hedera* under Three Light Levels. 18

III. Fresh and Dry Weight of the Aboveground Parts of *Liriope*, *Hosta*, and *Hedera* under Three Light Levels. 20

IV. Fresh and Dry Weight of the Underground Parts of *Liriope*, *Hosta*, and *Hedera* under Three Light Levels. 21

V. Starch Content of *Liriope*, *Hosta*, and *Hedera* under Three Light Levels. 22

VI. Chlorophyll Content Value of *Liriope*, *Hosta*, and *Hedera* under Three Light Levels 23

VII. P.P.M. of Nitrate and Potassium in Soil after Crop Was Harvested. 25

VIII. Height and Number of Leaves or Shoots of *Liriope*, *Hosta*, and *Hedera* in the Presence of Additional Nitrogen and Potassium 27

IX. Total Length of Shoots of *Hedera* in the Presence of Nitrogen and Potassium 28

TABLE | PAGE

X. Fresh and Dry Weight of the Aboveground Parts of _Liriope_, _Hosta_, and _Hedera_ in the Presence of Added Nitrogen and Potassium 29

XI. Fresh and Dry Weights of Underground Parts of _Liriope_, _Hosta_, and _Hedera_ in the Presence of Added Nitrogen and Potassium 30

XII. Starch in the Roots of _Liriope_, Rhizomes of _Hosta_, and Leaves of _Hedera_ in the Presence of Nitrogen and Potassium 32

XIII. Chlorophyll Content Value of _Liriope_, _Hosta_, and _Hedera_ in the Presence of Nitrogen and Potassium 33

CHAPTER I

INTRODUCTION

Ground covers are becoming more important in landscaping because they are easily grown and require little maintenance. They serve as a functional part of the landscape. They may be used on areas not suited for lawn grasses because of dense shade, or steep slopes. Combination of different ground covers can add interest to the landscape.

Little research on the response of ground covers to shade and fertility has been done. It is important to know whether the ground covers have a wide range of tolerance to light and whether mineral fertilization might increase the performance of the plants under various light conditions.

Ground covers used for this study were plantain lily, *Hosta fortunei*; lilyturf, *Liriope graminifolia*; and English ivy, *Hedera helix*. These three plants are evergreen perennials. They are different in form, texture, and methods of cover. *Hosta* has a large, broad leaf that provides dense glossy masses of foliage. This plant has thick, somewhat tuberous, durable perennial roots. The flowers are bell-shaped and loosely arranged on long, leafless flower stalks. Liriope is a stemless plant with smooth, grass-like foliage, growing from underground stolons or rhizomes. The small purplish to whitish flowers are produced on single spikes (20). Hedera is considered a vine, clinging to supports by aerial rootlets. It has lobed leaves that form a dense, coarse mat of foliage.

The three ground covers are being used in sun and shade indiscriminately. They are rarely fertilized. The objective of this study was to determine the response of Liriope, Hosta, and Hedera to various degrees of shade and to various levels of nitrogen and potassium.

CHAPTER II

REVIEW OF LITERATURE

I. ECOLOGICAL REQUIREMENTS OF GROUND COVERS

It has been recorded (2, 20) that both *Hosta* and *Hedera* like shady areas and grow in any kind of soil but grow best in a moist and rich one. *Liriope* grows in either sun or shady areas. Lee (13) also reported that *Hosta* does better in the shade than in the sun and will stand the dense shade to which many ferns are adapted. Hume and Morrison (10) reported that *Liriope* grows suitably in semi-shaded areas and is not particular about soil. To secure the best results, the soil should be enriched from time to time. As recorded in Plants and Gardens (24, 27), *Hosta* adapts itself to all degrees of shade, but it prefers the kind of shade that is high with openings to allow the entrance of air and light. Perhaps the best shade is that derived from tall pines. *Hedera* may be grown in medium shade receiving little sun throughout the day. The shade of a heavy oak forest is typical of the requirements of *Hedera*. *Liriope* is best grown in an open shade area with sun all morning and shade in the afternoon. The Florida Agricultural Experiment Station reports (7) that to maintain the vigorous growth of ground covers, in general, fertilizers containing 6 to 12 per cent nitrogen, 4 to 8 per cent phosphoric acid, and 4 to 10 per cent potash are satisfactory. Creeping Liriope is especially adapted to shady locations, doing well in partial to full shade. It is also grown in the full sun but is less satisfactory. Algerian ivy grows best in shade and poorly in full sunlight. It has been assumed that ivy grows best in a rich moist soil having a pH 5.0 to 6.5.

II. POSSIBILITIES OF MODIFYING ECOLOGICAL SITUATIONS

With Light

In studies on the American and European lawn grasses in Japan, Kitamura and Ozawa (11) concluded that reduced sunlight caused reductions in fresh and dry weight, number of stems and stolons, and the length and quantity of roots, but the height of grasses was increased.

Steponkus and Lanphear (23) reported that when ivy leaves were exposed to light at 6600 lux and were hardened at 5 C, the leaf hardiness, total sugar content and starch content were increased. When the leaves were kept dark at 5 C, the leaves were not very hardy. There was no effect on the total sugar content, and the starch content was greatly decreased. After dehardening by exposing the ivy leaves to 21 C in either light at 6600 lux or in the dark, starch synthesis was increased. The total sugar content of plants (leaves and stems) was decreased in the plants previously acclimated in the light but increased in plants previously acclimated in the dark. The rate of dehardening was more rapid in the plants previously hardened in the light than in the dark.

Taylor, et al., (25) reported that the stem diameter of Philodendron species was significantly increased by increasing the light intensity. From 90 per cent shade to 60-30 per cent shade, there was no response to nitrogen. Leaf area, color, stem length, and number of nodes were not affected by increasing light intensity. Rooting, bud break percentage, and root quality were not affected by nitrogen-light treatment.

Einert and Box (8) stated, in Easter lily studies, that a decrease in natural sunlight intensity resulted in an increase in plant height due to stem elongation. At the time of flower bud initiation, leaf chlorophyll content was highest under full sunlight and directly proportional to light intensity.

When all the information presented was evaluated, it appeared that English ivy, with its climbing habit and aerial roots like Philodendron and creeping stems like grasses, may need a great deal of sunlight.

When plantainlily and lilyturf were used as ground covers, it seemed that a reduction of sunlight could lead to an increase in plant height, and the amount and quality of growth could be lessened.

By Fertilization

In strawberry studies, it was reported that the application of calcium nitrate to the soil increased the total length of runners, the weight of roots and leaves, and the flower number per plant. The leaf and root growth was best at the highest N level (350 ppm). From the soil analysis, it was shown particularly that K decreased when the plants were fertilized with calcium nitrate. With an increasing N/K ratio, the foliar content of N and K were increased (14, 18, 26).

Harkness, *et al.*, (9) and LeMoyne, *et al.*, (12) in *Philodendron* species nutritional studies stated that K rates did not have an effect on vine length or number of nodes, but the addition of K increased the fresh weight, due to the heavier stem and larger, heavier leaves produced. Leaf analysis showed that a high nitrogen concentration in the soil did not greatly increase the nitrogen content of the leaves, but it caused a marked reduction of the potassium content.

Serley and Dolores (19) reported that the application of additional nitrogen to Croft lilies during the growing period, produced shorter plants than when not fertilized.

The amount of leaf burn was less, and the lilies had better foliage when nitrogen was applied.

All the nutrition research showed that nitrogen and potassium promoted the growth of plants.

Light and Fertilization

Bensink (3) studied the effect of light intensity in lettuce at different nitrate concentrations. He reported that at each nitrogen level, with decreasing light intensity, the relative leaf length (the ratio of total leaf length to the greatest leaf width) was increased.

In 1938, Blackman (4) studied the effects of light and nitrogen on a sward of *Agrostis* spp. and clover (*Trifolium repens*). He reported that there was a marked interrelationship between light and nitrogen effects. Under different light intensities (full daylight; 0.61-0.63 of daylight; 0.44-0.37 of daylight), the addition of calcium nitrate and ammonium sulphate diminished the clover content. This reduction was more apparent in low light intensity than high light intensity lots. The reduction of clover content associated with the additional nitrogen was due to the competition for light between the clover and the grasses. When the sward was infrequently defoliated, grass growth was increased by increased supplies of nitrogen, but the growth of clover was not limited by it. The more rapidly growing grasses shaded the clovers and depressed the clover content.

Later, Blackman and Templeman (5) studied again the influence of light intensity and nitrogen supply on the leaf production of grasses (*Agrostis tenuis* and *Festuca rubra*) and *Trifolium repens* when the plants were grown in pots and were frequently defoliated by shears. They found that in full daylight both calcium nitrate and ammonium sulphate increased the leaf production of clover to a small extent and that of the grasses to a large extent. When light intensity was reduced, the reaction of grasses and clover to additional nitrogen was different. In clover, the shading effect resulted in lowering of leaf production regardless of the application of nitrogen. In the shaded grasses, the addition of nitrogen reduced the production of leaves, and the depression was emphasized with each successive defoliation.

In 1940, Blackman and Templeman (6) studied the relation of light intensity and nitrogen supply to the metabolism of leaves of grasses (*Agrostis tenuis* and *Festuca rubra*). From analysis of dry leaves, they found that in full daylight, the addition of calcium nitrate and ammonium sulphate increased the total nitrogen content in the leaves which was largely found in the form of protein. Under shaded conditions, plants receiving ammonium sulphate contained more total nitrogen, more protein, and less nitrate in their leaves than those given calcium nitrate treatment. Shading reduced leaf carbohydrate content by 20 to 60 per cent. In general, under different light intensities, the addition of ammonium sulphate and calcium nitrate led to increase in total organic acids.

All the statements suggested that rates of application of fertilizer were related to light intensity.

The relationships between plants and light intensity were quite different from species to species. Under different light intensity, the reaction of a species to fertilization may be similar to or different from other species.

CHAPTER III

MATERIALS AND METHODS

General Procedure

Uniform, rooted cuttings of *Hedera helix* and rhizomes of *Hosta fortunei* were set in 4 inch pots. *Liriope graminifolia* was grown in 4 inch pots. The plants were divided into quarters, and the bottom third of the soil mass was discarded. Each quarter was planted in a new 4 inch pot. The pots were filled with a mixture of two parts clay, one part sand, one part peat, and 2 grams of 20 per cent superphosphate. The potting medium contained 5.75 ppm of available phosphate after mixing.

Each potted *Hedera* had one stem of eight nodes, with leaves on the upper four. *Liriope* was reduced to single crowns. Two rhizomes of *Hosta*, each with two folded leaves, were set in each pot.

There were a total of 504 pots, 144 pots of *Hedera* and 180 pots each of *Hosta* and *Liriope*. One third of these pots, 48 pots of *Hedera* and 60 pots each of *Hosta* and *Liriope* were placed in an open area under each of three different light conditions: full sunlight, half of full sunlight, and a quarter of full sunlight. Light was controlled by Saran shade cloth. One fourth of these pots, 12 pots of *Hedera* and 15 pots each of *Hosta* and *Liriope* received 3.8 g of NH_4NO_3 and 6.0 g of K_2SO_4, high N low K, (HNLK); one fourth received 3.8 g of NH_4NO_3 and 60.3 g of K_2SO_4, high N high K (HNHK); one fourth received no NH_4NO_3 and 6.0 g of K_2SO_4, low N low K (LNLK); the last fourth received no NH_4NO_3 and 60.3 g of K_2SO_4, low N high K (LNHK). These four different combinations of nitrogen and potassium were dissolved in 4500 ml water and 100 ml applied to each pot after the plants were set in the pots and were under different light conditions on May 5, 1971. It was determined by the Spurway (22) soil testing method that after fertilization, the pots receiving no nitrogen had about 2 ppm of NO_3; the pots receiving 3.8 g of NH_4NO_3 had about 25 ppm of NO_3; the pots receiving 6.0 g and 60.3 g of K_2SO_4 had 2.5 ppm and 25 ppm of K, respectively.

The 168 pots under each light intensity were arranged in three replicas, always starting with *Liriope* to the right; *Hosta* and *Hedera* followed in successive order. In each replica, there were 20 pots each of *Liriope* and *Hosta*, 16 pots of *Hedera*. Each group of pots of *Liriope* and *Hosta* and *Hedera* was divided into four equal sized subgroups.

From September 15 to 17, *Liriope*, *Hosta*, and *Hedera* were harvested individually. All of the plants of each species receiving the same fertilizer treatment in each replicate were used in sampling for analysis. These samples were divided into aboveground and underground portions. The aboveground portion included the stem and leaves with petiole of Hedera and leaves of Hosta and Liriope. The underground portion included roots of Hedera and Liriope, and the rhizome and roots of Hosta.

All the samples, including the aboveground and underground portions, were weighed separately, and the fresh weights recorded. They were then oven-dried at 70 C for 24 hours. The residue was considered as the dry weight. All the dry matter samples were ground separately through an 80 mesh screen and stored in glass bottles.

The leaf chlorophyll content was measured using a 0.01 g aliquot of the ground dry matter. Starch content was measured using 0.25 g aliquot of the ground dry matter of Liriope root, Hosta crown with rhizome, and Hedera leaves.

The height of the plant, number of leaves, number of shoots and total shoot length were measured on September 15. The standard of height was from the soil level to the tip of the tallest leaf.

The soil samples were made by taking one inch central cores from each pot in each subgroup.

Chemical Analysis

Soil testing. The Simplex Soil Testing System of the

Edwards Laboratory, originated by Spurway (22), was used in this experiment.

Chlorophyll determination. A 0.01 g sample of dry ground leaves was used and put in a test tube. Five ml anhydrous acetone was added to the tube and a stopper was used. Then it was placed in a shaker to extract the chlorophyll. The chlorophyll extract was diluted to 25 ml with anhydrous acetone. From this solution, samples were taken to read the optical density (absorption) in the spectrophotometer at 645 nm and 663 nm. The constants calculated by Aron (1) and Mackinney (15) were used in the following formulae:

$$\text{Total chlorophyll (mg/l)} = 20.2\, D_{645} + 8.02\, D_{663}$$

$$\text{Chlorophyll a (mg/l)} = 12.7\, D_{663} - 2.69\, D_{645}$$

$$\text{Chlorophyll b (mg/l)} = 22.9\, D_{645} - 4.68\, D_{663}$$

Starch determination. A 0.25 g dried and ground sample was weighed out and placed in a 125 Erlenmeyer flask with 10 ml of distilled water and refluxed for half an hour in a boiling water bath. A 25 ml Erlenmeyer flask was inverted and inserted into the mouth of the larger flask as a condenser. The sample was cooled to room temperature. Ten ml of buffer solution (16) and 10 ml of Clarase solution (16) were added to the sample which was incubated at 37 C for 44 hours.

After incubation, the sample was filtered through Whatman No. 42 filter paper. The residue was washed with 5 ml of 0.7 N HCL, and the filtrate was refluxed for half an hour in a boiling water bath as described above to complete hydrolysis. After refluxing, the sample was filtered again through Whatman No. 42 filter paper and brought to 250 ml volume with distilled water.

A one ml aliquot was pipetted into a 50 ml Erlenmeyer flask to which 1 ml distilled water and 2 ml copper reagent (21) were added. A big marble was placed on top of the flask as a reflux condenser, and the flask was heated in a boiling water bath for 15 minutes. The sample was cooled to room temperature and 2 ml of arsenomolybdenate reagent (21) and 20 ml of distilled water were added. A 10 ml sample was transferred into a standard test tube, and the reading was made by using a spectrophotometer set at 510 nm.

Aliquots of 5, 10, 15, 20, and 25 ml were taken from D-glucose stock solution (1 mg/ml) and diluted individually with water to 100 ml. From each of these standard glucose solutions, 2 ml aliquots were transferred to a 25 Erlenmeyer flask. Two ml copper reagent (21) was added, and the solution was handled as described above.

Optical density of the standard glucose solutions was taken with a spectrophotometer at 510 nm. The optical density was plotted against the concentration of standard glucose solutions, and a straight line was obtained. The slope of this line was used as the conversion factor. The milligram per milliliter of glucose presented in the sample was obtained by multiplying the optical density by the slope of the curve.

The percentage of glucose was calculated by the equation:

$$\text{Per cent glucose} = \frac{\text{mg glucose/ml in sample}}{\text{mg dry matter/ml in sample}} \times 100$$

The per cent of starch was obtained by the following formula:

$$\text{Per cent starch} = \frac{\text{per cent glucose}}{111.1} \times 100$$

The second formula was used since 100 parts of starch should theoretically yield 111.1 parts of glucose (17).

CHAPTER IV

RESULTS AND DISCUSSION

All the data are shown in the tables as number of leaves or shoots, heights, lengths and weights of plants throughout the discussion. They will be discussed in two parts: light and fertilization. Each datum presented in each table is the average of the various measurements of the plants of each species grown in five pots each of *Liriope* and *Hosta* and four of *Hedera*.

I. LIGHT

The height of *Liriope*, *Hosta*, and *Hedera*, the number of leaves of *Liriope* and *Hosta*, and the number of shoots of *Hedera* obtained at the end of the experiment are displayed in Table I. The height of all three species increased with increasing shade. Under shaded conditions, the number of leaves of *Liriope* and *Hosta* was greater than in full sunlight.

Hedera produced no more shoots under shaded conditions than when unshaded. However, according to Table II, *Hedera* did produce longer shoots under shaded conditions.

Measurements of height, length and numbers provide some information on the visual appearance under the different light treatments. In order to become acquainted with

TABLE I

HEIGHT AND NUMBER OF LEAVES OR SHOOTS OF *LIRIOPE*, *HOSTA*, AND *HEDERA* PRODUCED UNDER THREE LIGHT LEVELS

Per Cent of Full Sunlight	*Liriope*		*Hosta*		*Hedera*	
	Height cm	Number of Leaves	Height cm	Number of Leaves	Height cm	Number of Shoots
25	62.03	93.42	87.63	73.42	121.92	10.50
50	57.35	93.17	78.21	71.50	116.54	11.17
100	48.46	73.92	53.87	61.17	93.88	10.50
LSD at 5%	3.45	10.54	6.07	9.20	18.34	N.S.

TABLE II

TOTAL LENGTH OF SHOOTS OF *HEDERA* UNDER THREE LIGHT LEVELS

Per Cent of Full Sunlight	Total Length of *Hedera* Shoots
	cm
25	139.70
50	138.63
100	99.70
LSD at 5%	34.77

the ability of the plants to produce food and structural materials, fresh and dry weights were taken and storage organs were analyzed to obtain the starch content. These data are shown in Tables III, IV, and V.

Table III indicates that among the three ground covers only Hosta showed considerable difference in fresh and dry weights of leaves under the three light conditions. Hosta had greater fresh and dry weights under shaded conditions. Liriope and Hedera showed little difference in ability to produce structural materials. However, they appeared to follow the same trend as Hosta. The fresh and dry weights of roots suggested a similar trend, but the variations between pots were so great that significance could not be demonstrated.

Starch data, shown in Table V, were collected from roots of Liriope. Difference between sunlight treatments was not demonstrated.

The rhizomes of Hosta showed differences indicating that the greatest starch content was produced under low or moderate light conditions. The starch content of the rhizomes under 50 per cent of sunlight was not different from those under 25 per cent of sunlight. The plants from both shade levels had a starch content greater than those under full sunlight, which had 37 per cent.

Chlorophyll content values are shown in Table VI.

TABLE III

FRESH AND DRY WEIGHT OF THE ABOVEGROUND PARTS OF *LIRIOPE*, *HOSTA*, AND *HEDERA* UNDER THREE LIGHT LEVELS

Per Cent of Full Sunlight	*Liriope* Leaves Fresh Weight	*Liriope* Leaves Dry Weight	*Hosta* Leaves Fresh Weight	*Hosta* Leaves Dry Weight	*Hedera* Leaves Fresh Weight	*Hedera* Leaves Dry Weight	*Hedera* Stems Fresh Weight	*Hedera* Stems Dry Weight
	Grams							
25	4.05	0.91	26.95	4.83	9.28	3.70	5.60	2.08
50	4.07	0.93	22.04	4.15	8.71	3.19	5.98	1.68
100	2.71	0.87	12.27	2.58	6.84	2.43	4.33	1.58
LSD at 5%	N.S.	N.S.	5.23	1.46	N.S.	N.S.	N.S.	N.S.

TABLE IV

FRESH AND DRY WEIGHT OF THE UNDERGROUND PARTS OF LIRIOPE, HOSTA, AND HEDERA UNDER THREE LIGHT LEVELS

Per Cent of Full Sunlight	Liriope Roots		Hosta Rhizomes		Hedera Roots	
	Fresh Weight	Dry Weight	Fresh Weight	Dry Weight	Fresh Weight	Dry Weight
			Grams			
25	14.14	2.63	15.06	4.79	11.15	2.62
50	14.13	3.75	13.07	4.14	10.73	2.59
100	18.36	3.63	14.19	4.53	8.61	2.49
LSD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

TABLE V

STARCH CONTENT OF LIRIOPE, HOSTA, AND HEDERA
UNDER THREE LIGHT LEVELS

Per Cent of Full Sunlight	Liriope In Roots	Hosta In Rhizomes	Hedera In Leaves
		Per Cent Dry Matter	
25	36.19	41.85	63.46
50	37.40	44.42	68.45
100	35.51	37.26	60.49
LSD at 5%	N.S.	3.65	4.18

TABLE VI

CHLOROPHYLL CONTENT VALUE OF LIRIOPE, HOSTA, AND HEDERA UNDER THREE LIGHT LEVELS

Per Cent of Full Sunlight	Liriope			Hosta			Hedera		
	*CA	**CB	***TC	CA	CB	TC	CA	CB	TC
					mg/1				
25	1.38	0.54	1.97	1.19	1.00	2.06	0.51	0.85	1.48
50	1.71	0.78	2.48	1.25	1.02	2.51	0.62	0.62	1.44
100	1.01	0.70	1.63	1.29	1.09	2.26	0.61	0.86	1.47
LSD at 5%	0.26	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

*CA chlorophyll a

**CB chlorophyll b

***TC total chlorophyll

In Hosta and Hedera, significant variation of chlorophyll a,b and total chlorophyll content due to light intensities was not observed.

In Liriope, chlorophyll a content was higher under shaded conditions than unshaded conditions. Chlorophyll b and total chlorophyll content did not differ under the different light levels.

In terms of the food production, it would seem that Hosta and Hedera might function better under partial or heavy shade than under full sunlight. Liriope did not appear to be as greatly influenced as Hosta and Hedera by light treatments in this respect.

The residual quantities of NO_3^- and K^+ ions in the growth media seem to indicate something about the movement of these two ions from the soil to the different plants in respect to their different growth habits.

Table VII showed that the media in pots containing Hosta in shade retained more NO_3^- than the media in the unshaded pots. It seems peculiar that such large differences in NO_3^- and K^+ show up at the end of the experiment between the media of the shaded and unshaded pots, since as discussed before, Hosta attained much more growth under shade than under full sunlight. It seems that the greater growth of Hosta was not made at the expense of the available NO_3^- and K^+ ions in the soil solution. If this was a question

TABLE VII

P.P.M. OF NITRATE AND POTASSIUM IN SOIL AFTER CROP WAS HARVESTED

Per Cent of Full Sunlight	Liriope		Hosta		Hedera	
	NO_3	K	NO_3	K	NO_3	K
25	3.83	3.54	6.58	3.54	3.42	3.75
50	3.25	3.54	7.50	3.54	4.41	3.96
100	4.83	2.79	3.42	2.50	4.41	3.95
LSD at 5%	N.S.	N.S.	2.56	0.86	N.S.	N.S.

of less leaching due to less watering, it should also have showed the same difference in _Liriope_ and _Hedera_ pots.

II. FERTILIZATION

Additional nitrogen increased the height of all these species significantly as shown in Table VIII. The addition of potassium depressed height in the case of _Liriope_.

It was also found in Table VIII that the number of leaves of _Liriope_ and _Hosta_ and the number of shoots of _Hedera_ were noticeably greater in the presence of high nitrogen.

Total length of shoots of _Hedera_ was much greater with the addition of high nitrogen, while it was significantly less with high potassium supply (Table IX).

The fresh and dry weight of _Liriope_ and _Hosta_ leaves and _Hedera_ stems were considerably greater with additional nitrogen than with low nitrogen according to Table X. This also appeared to be true in _Hedera_ leaves, but significant differences at the 5 per cent level were not shown. The fresh weight of leaves of _Hedera_ was notably less with high potassium.

As shown in Table XI, both fresh and dry weights of the roots of _Hedera_ were positively affected by the high nitrogen level.

TABLE VIII

HEIGHT AND NUMBER OF LEAVES OR SHOOTS OF LIRIOPE, HOSTA, AND HEDERA IN THE PRESENCE OF ADDITIONAL NITROGEN AND POTASSIUM

	Liriope		Hosta		Hedera	
Fertilizer	Height cm	Number of Leaves	Height cm	Number of Leaves	Height cm	Number of Shoots
HN	61.95	97.56	76.76	71.67	120.09	12.44
LN	49.96	76.11	69.70	65.72	100.48	9.00
HK	53.98	83.56	74.50	69.06	105.84	10.39
LK	57.94	90.11	71.96	68.33	115.72	11.06
LSD at 5% for Nitrogen	3.66	14.57	6.73	4.72	15.98	1.54
LSD at 5% for Potassium	3.45	N.S.	N.S.	N.S.	N.S.	N.S.

TABLE IX

TOTAL LENGTH OF SHOOTS OF *HEDERA* IN THE PRESENCE OF NITROGEN AND POTASSIUM

Fertilizer	Total Length of *Hedera* Shoots
	cm
HN	151.56
LN	100.48
HK	115.14
LK	136.88
LSD at 5% for Nitrogen	31.60
LSD at 5% for Potassium	20.80

TABLE X

FRESH AND DRY WEIGHT OF THE ABOVEGROUND PARTS OF *LIRIOPE*, *HOSTA*, AND *HEDERA* IN THE PRESENCE OF ADDED NITROGEN AND POTASSIUM

Fertilizer	*Liriope* Leaves		*Hosta* Leaves		*Hedera* Leaves		*Hedera* Stems	
	Fresh Weight	Dry Weight	Fresh Weight	Dry Weight	Fresh Weight	Dry Weight	Fresh Weight	Dry Weight
	Grams							
HN	4.51	1.27	22.43	4.27	9.43	3.49	6.47	2.23
LN	2.71	0.53	18.41	3.44	7.12	2.73	4.13	1.34
HK	3.36	0.81	20.88	3.91	7.07	2.91	5.03	1.95
LK	3.86	1.00	19.96	3.80	9.48	2.31	5.57	1.62
LSD at 5% for Nitrogen	1.66	0.30	3.40	0.73	N.S.	N.S.	0.73	0.75
LSD at 5% for Potassium	N.S.	N.S.	N.S.	N.S.	1.46	N.S.	N.S.	N.S.

TABLE XI

FRESH AND DRY WEIGHTS OF UNDERGROUND PARTS OF *LIRIOPE*, *HOSTA*, AND *HEDERA* IN THE PRESENCE OF ADDED NITROGEN AND POTASSIUM

Fertilizer	*Liriope* Roots		*Hosta* Rhizomes		*Hedera* Roots	
	Fresh Weight	Dry Weight	Fresh Weight	Dry Weight	Fresh Weight	Dry Weight
			Grams			
HN	5.01	3.77	15.07	4.73	11.63	2.93
LN	4.25	2.91	13.14	4.25	8.70	2.21
HK	4.72	3.08	14.13	4.36	9.59	2.43
LK	4.54	3.59	14.08	4.62	10.73	2.71
LSD at 5% for Nitrogen	N.S.	N.S.	N.S.	N.S.	1.54	0.44
LSD at 5% for Potassium	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

No effects were found on starch accumulation in the roots of *Liriope*, rhizomes of *Hosta*, and leaves of *Hedera* due to the supply of nitrogen and potassium. It was apparent that starch accumulation was affected by light rather than mineral supply (Table XII).

A study of chlorophyll content did not show any difference due to different levels of nitrogen and potassium (Table XIII).

The data collected from the responses of these three ground cover species to the different levels of nitrogen and potassium fertilization provide several possibilities for management.

Among these, to sustain a normal growth of the ground covers under the conditions of this experiment, Table VII, page 25, suggests that the soil solution at 3.2 to 7.5 ppm of nitrate and 2.8 to 4.0 ppm of potassium seems to be adequate for their growth.

TABLE XII

STARCH IN THE ROOTS OF *LIRIOPE*, RHIZOMES OF *HOSTA*, AND LEAVES OF *HEDERA* IN THE PRESENCE OF NITROGEN AND POTASSIUM

Fertilizer	*Liriope* in Roots	*Hosta* in Rhizomes	*Hedera* in Leaves
		Per Cent Dry Matter	
HN	36.00	40.95	65.89
LN	36.72	41.40	62.38
HK	35.91	41.31	63.73
LK	36.81	41.01	64.54
LSD at 5% for Nitrogen	N.S.	N.S.	N.S.
LSD at 5% for Potassium	N.S.	N.S.	N.S.

CHAPTER V

SUMMARY AND CONCLUSION

A study of the growth of Liriope, Hosta, and Hedera under three light levels and two levels of nitrogen and potassium, expressed in height, fresh and dry weights, number of leaves or shoots, length of total shoots, and chlorophyll and starch content, was carried out from May to September of 1971.

Both light and fertilizer treatment factors significantly influenced the appearance of the plants. In general, shaded conditions and a relatively high nitrogen level increased the growth of plants as indicated by taller plants with more leaves and longer shoots.

Starch content appeared to be more affected by light than by fertilizer. In Hosta and Hedera, the medium shade (50 per cent of full sunlight) is suggested as optimum for starch accumulation.

Generally speaking, the three ground covers responded more to nitrogen supply than to potassium.

In terms of the fresh and dry weights of these species, nitrogen seemed to have more effect on stems and leaves than on underground parts.

It was suggested from this experiment that these three ground covers, Liriope, Hosta, and Hedera grow better under medium to dense shade. They might grow under full sunlight, but appearance is often poor. A small amount of nitrogen and potassium appears to be sufficient for the normal growth of these ground covers.

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