CHAPTER 2

THE EFFECT OF STAGE OF DEVELOPMENT ON PHOTOSYNTHESIS, DARK RESPIRATION, AND DISTRIBUTION OF ^{14}C-PHOTOSYNTHATE IN MERION KENTUCKY BLUEGRASS (*POA PRATENSIS* L.) AND PENNLAWN RED FESCUE (*FESTUCA RUBRA* L.)

Abstract

The effects of stage of development on net photosynthesis, dark respiration and distribution of ^{14}C-photosynthate in Merion Kentucky bluegrass (*Poa pratensis* L.) and Pennlawn red fescue (*Festuca rubra* L.) were evaluated. Lateral shoot development occurred after the third (3 weeks after seedling emergence) and fifth leaf stage (3 to 4 weeks after seedling emergence) in Pennlawn red fescue and Merion Kentucky bluegrass, respectively. Tillers were initiated in the axils of leaves below fully expanded leaves in both species. Tiller development preceded rhizome initiation in red fescue; whereas, tillers and rhizomes were not initiated preferentially to one another in Merion Kentucky bluegrass. High dark respiration rates and a large percentage of leaf dry weight occurred at the first sampling period. The percent distribution of ^{14}C-photosynthate shifted from the leaves to stems between the second and third week after seedling emergence in Kentucky bluegrass; whereas, this shift occurred between the third and fourth week after seedling emergence in red fescue. The stem fractions were the dominant sinks for photosynthate after the second and third week following seedling emergence in Pennlawn red fescue and Merion Kentucky bluegrass, respectively.

The changes in these morphological and physiological responses during seedling growth may indicate critical developmental periods.

Introduction

Effective turfgrass management requires knowledge of the physiological and morphological changes associated with its growth and development. Rapid, successful turfgrass establishment is required for effective dust and erosion control. Delays in establishment will increase the likelihood of soil loss by erosion.

Few turfgrass investigations have described the physiological plant responses associated with growth and development. DeFrance and Simmons (7) briefly characterized the relative growth patterns of three cool season turfgrasses during seedling development. Tiller and rhizome development has been correlated with the early stages of turfgrass growth and shown to be dependent on species and environmental conditions (3, 4, 11).

The photosynthetic-respiratory balance can be a critical factor during plant growth and development. Net photosynthesis and dark respiration have been reported to vary independently from the stage of plant maturity (5, 9, 17).

Photosynthate distribution depends on assimilate supply and demand and usually reflects areas of active metabolism (5, 6, 14). Carpenter (5) measured photosynthate distribution during seedling growth in dicotelydons and reported a gradual shifting of metabolic activity from leaves to stems and finally to roots. Nyahoza (12) reported enhanced movement of photosynthate into developing rhizomes during seedling growth in Kentucky bluegrass.

The objectives of this study were to investigate the morphological and physiological changes occurring during seedling development in turfgrass. Net photosynthesis, dark respiration, and distribution of ^{14}C-photosynthate were measured in order to estimate the energy balance and monitor shifts

in metabolic activity within the plant. Plant age, leaf stage, and leaf positioning were also measured during the various phases of lateral shoot development. This information could provide insight into more effective establishment practices and an understanding of the development patterns associated with turfgrass growth.

Materials and Methods

Cultivars of Merion Kentucky bluegrass and Pennlawn red fescue were selected based on their dominant use in temperate regions. Plants of each species were grown from seed in 5 cm diameter by 15 cm deep plastic containers filled with washed silica sand and having perforated bases for free drainage. Each specie was seeded at 15 to 20 seeds per pot and the seedlings thinned gradually to one plant per pot at the end of 4 weeks. The higher plant density provided sufficient plant material for accurate sub-sampling during the early growth stages. Later thinning was done to minimize competition and reduce interleaf shading during photosynthetic measurements.

The germinated seedlings were grown in an environmental growth chamber at 23 C day and 16 C night temperatures. Light radiation level was 1000 $\mu E\ M^{-2}\ sec^{-1}$. Relative humidity ranged between 65 to 75% and the photoperiod was 14 hours. A nutrient solution drench (8) was applied every third day and plants irrigated with tap water on alternate days. Weekly clipping was initiated 4 weeks after seedling emergence at a height of 7.6 cm.

Photosynthesis, dark respiration, and distribution of ^{14}C-photosynthate were measured using methods previously described (10). The plants were returned to the environmental growth chambers after labelling for a 24 hour period. The root system was washed free of sand, immediately frozen with dry ice, and stored in a -10 C freezer. Plants were subsequently sectioned into leaf, root, stem, and rhizome fractions and freeze dried.

The leaf fraction consisted of leaf tissue located above the collar. The crown and leaf sheath were included in the stem fraction. Root segments were removed from below and immediately adjacent to the crown. The rhizome fraction consisted of subsurface secondary lateral shoots that developed extravaginally and extended horizontally. Only those rhizomes that emerged into the light and formed photosynthetically active leaf tissue were separated into leaf and stem fractions.

Leaf area measurements were made with a LI-COR, Model LI-3000 portable area meter using a subsample of fresh leaf blades (5 to 10). Measurements were taken weekly and a leaf area : leaf weight ratio was determined for calculation of total leaf area.

Each measurement was replicated three times on separate plants and a completely randomized block analysis of variance used. Differences between treatment means were tested statistically using Duncan's Multiple Range Test.

Results and Discussion

Pennlawn red fescue initiated lateral shoots only after the third leaf stage of development (approximately 3 weeks after seedling emergence). Merion Kentucky bluegrass initiated lateral shoots after the fifth leaf stage (approximately 3 to 4 weeks after seedling emergence). These results indicate that a specific level of maturity or developmental stage is required before lateral shoot development can occur. Soper (16) also reported distinct levels in maturity at which tillers were initiated in perennial ryegrass (*Lolium perenne* L.)

Tiller development in both species occurred only in the axils of leaves below fully expanded leaves. Similar leaf positioning has been reported in other grasses undergoing tiller development (13). Tiller development in red fescue preceded rhizome initiation in all observations. However, in Merion Kentucky bluegrass, neither tillers nor rhizomes were initiated preferentially to one another.

The percent distribution of dry weight during turfgrass seedling development is shown in Table 1. Both species showed similar distribution patterns. The percent distribution of dry weight in the root fraction tended to increase from the initial sampling to 3 weeks after seedling emergence. The leaf fraction showed enhanced percent dry weight accumulation during the first 2 weeks. This trend was followed by some slight differences, however, these variations did not follow a noticeable trend in either species. The proportion of dry weight in the stem fraction in Merion Kentucky bluegrass increased gradually from the second sampling period to the eighth week of development. The percent of stem dry weight dropped at the last sampling period and corresponds to a significant increase in rhizome growth. These changes in the percent dry weight distribution reflect inherent shifts in the developmental growth pattern. This type of information should provide a greater understanding of turfgrass growth and development.

Variations in net photosynthate and dark respiration during the ten week sampling period were similar for both species (Table 2). Higher photosynthetic rates occurred at the initial sampling period only. Dark respiration rates were accelerated 1 and 2 weeks after seedling emergence. Rates were greatest one week after emergence and declined to one-half the original level at the second sampling period. This initial acceleration in respiration may indicate a time sequence of high energy demands. Heightened photosynthetic

rate at the initial sampling period corresponded with a high percent leaf dry weight and may indicate a plant response designed for high photosynthate output.

The percent distribution of photosynthate shifted significantly from the leaves to the stems in both species (Table 3). This shift occurred between the third and fourth sampling periods in Pennlawn red fescue and second and third sampling periods in Merion Kentucky bluegrass. Rhizome development followed 1 week after and this shift in distribution may be a factor related to the initiation of secondary lateral shoot development. The percent distribution of ^{14}C-photosynthate in the root fraction declined during rhizome development in both Merion Kentucky bluegrass and Pennlawn red fescue. Rhizome development has been shown to act as a noticeably strong sink within plant systems and alters photosynthate distribution (6, 12). The relationship between rhizome development and decline in percent accumulation of photosynthate in the roots may indicate that rhizome development occurs at the expense of root growth. The stem fraction showed a high percentage of ^{14}C-photosynthate accumulation. Stem tissue has been reported as a major region of carbohydrate storage in grasses (1, 2, 15).

Proper selection of planting dates for optimal environmental growth conditions (15-20 C) and cultural practices for adequate moisture and nutrient availability during these marked changes in seedling development may be an important key to rapid and successful turfgrass establishment.

Literature Cited

1. Adegbola, A. A. and C. M. McKell. 1966. Effect of nitrogen fertilization on the carbohydrate content of coastal bermudagrass (Cynodon dactylon L. Pers.). Agron. J. 58:60-64.

2. Alberda, T. 1957. The effects of cutting, light intensity, and night temperature on growth and soluble carbohydrate content of Lolium perenne L. Plant and Soil. 8:199-230.

3. Alburquerque, H. E. 1967. Leaf area, and age, and carbohydrate reserves in the regrowth of tall fescue (Festuca arundinacea Schreb.) tillers. Ph.D. Thesis. Virginia Polytechnic Institute. pp. 1-278.

4. Areda, H., R.E. Blaser and R. H. Brown. 1966. Tillering and carbohydrate contents of orchardgrass as influenced by environmental factors. Crop Sci. 6:139-143.

5. Carpenter, S. L. 1971. Developmental changes in assimilation and translocation of photosynthate in Black Walnut (Juglans nigra L.) and Honeylocust (Gleditsia triacanthus L.) seedlings. Ph.D. Thesis. Michigan State University. pp. 1-85.

6. Crafts, A. S. and C. E. Crisp. 1971. Phloem transport in plants. W. H. Freeman and Co., San Francisco, Calif. pp. 127-156.

7. DeFrance, J.A. and J. A. Simmons. 1951. Relative period of emergence and initial growth of turfgrasses and their adaptability under field condition. Proc. of the Am. Soc. for Hort. Sc. 57:439-442.

8. Hoagland, C. R. and D. I. Aron. 1950. The water culture method for growing plants without soil. Calif. Agri. Expt. Sta. Circ. 347 pp. 32.

9. Kortschak, H. P. and A. Forkes. 1969. The effect of shade and age on the photosynthesis rate of sugar cane. In: Metzner, H. (ed.): Progress in Photosynthesis Research. Vol. 1 pp. 383-387.

10. Krans. J. V. 1975. The effects of cutting height and mowing frequency on net photosynthesis, dark respiration, and distribution of ^{14}C-photosynthate in Merion Kentucky bluegrass. In: The effects of cutting height and mowing stage of development, and reduced light intensities on net photosynthesis, dark respiration, and distribution of ^{14}C-photosynthate in cool season turfgrasses. Chapter 1. Ph.D. Thesis. Michigan State University.

11. Mitchell, K. J. 1953. Influence of light and temperature on the growth of ryegrass (Lolium spp.). II. The control of lateral bud development. Physiol. Plant. 6:425-443.

12. Nyahoza, J. L. 1973. The interrelationship between tillers and rhizomes of Poa pratensis L. - an autoradiographic study. Weed Sci. 21:304-309.

13. Patel, A. S. and J. P. Cooper. 1961. The influence of several changes in light energy on leaf and tiller development in ryegrass, timothy and meadow fescue. J. of the British Grassland Soc. 16:299-308.

14. Quinland, J. D. and G. R. Sagar. 1969. An autoradiographic study of the movement of ^{14}C-labelled assimilates in the developing wheat plant. Weed Res. 2:264-273.

15. Smith, D. 1968. Carbohydrates in grasses. IV. Influence of temperature on the sugar and fructosan composition of timothy plant parts at anthesis. Crop Sci. 8:331-334.

16. Soper, K., and K. J. Mitchell. 1956. The developmental anatomy of perennial ryegrass (Lolium perenne L.). New Zealand J. of Sci. and Tech. Sec. A. 37:484-504.

17. Wilson, D. and J. R. Cooper. 1969. Apparent photosynthesis and leaf characters in relation to leaf position and age, among contrasting Lolium genotypes. New Phytol. 68:645-655.

Table 1. The effect of stage of development on the percent distribution of dry weight in Pennlawn red fescue and Merion Kentucky bluegrass.

Species	Plant Tissue	Percent distribution of dry weight*								
		Sampling period (wk)								
		1	2	3	4	5	6	7	8	10
		%								
Pennlawn red fescue	Roots	19 a**	29 b	36 cd	33 bcd	35 cd	33 bcd	34 bcd	30 bc	32 bcd
	Stems	24 a	18 b	18 b	21 ab	26 a	23 ab	21 ab	25 a	24 a
	Leaves	57 a	53 a	46 b	46 b	38 c	43 bc	44 bc	44 bc	42 bc
	Rhizomes	0 a	0 a	0 a	0 a	1 a	1 a	1 a	1 a	4 b
Merion Kentucky bluegrass	Roots	21 a	27 b	34 c	30 bc	30 bc	35 c	32 bc	30 bc	29 bc
	Stems	20 ab	17 a	20 ab	22 b	27 cd	28 cd	28 cd	30 d	24 bc
	Leaves	59 a	56 a	46 b	47 b	40 c	36 c	37 c	37 c	41 c
	Rhizomes	0 a	0 a	0 a	1 a	2 a	2 a	3 b	3 b	6 c

* Values represent the percent dry weight based on total plant weight.

**Means within rows (across) with common letters are not significantly different at the 5% level by the Duncan's Multiple Range Test.

Table 2. The effect of stage of development on the net photosynthetic (P_N) and dark respiration (R_D) in Merion Kentucky bluegrass and Pennlawn red fescue.

Species	Plant measurement	Net photosynthesis and dark respiration* Sampling period (wk) 1	2	3	4	5	6	7	8	10
		$MgCO_2$ dm^{-2} hr^{-1}								
Pennlawn red fescue	P_N	41 a	23 bc	22 bc	26 b	20 bc	21 bc	20 bc	20 bc	17 c
	R_D	13 a	7 b	5 c	4 c	4 c	4 c	5 c	5 c	4 c
Merion Kentucky bluegrass	P_N	34 a	15 b	16 b	17 b	16 b	18 b	15 b	14 b	14 b
	R_D	16 a	8 b	5 c	5 c	4 c	4 c	5 c	4 c	5 c

*Means within rows (across) with common letters are not significantly different at the 5% level by the Duncan's Multiple Range Test.

Table 3. The effect of stage of development on the percent distribution of ^{14}C-photosynthate in Pennlawn red fescue and Merion Kentucky bluegrass.

Species	Plant tissue	Percent distribution of ^{14}C-photosynthate*								
		Sampling period (wk)								
		1	2	3	4	5	6	7	8	10
Pennlawn red fescue	Roots	27 a**	20 b	21 ab	19 b	16 bcd	17 bc	12 cd	10 d	10 d
	Stems	26 a	25 a	32 ab	49 bc	53 bcd	51 bc	48 bc	55 cd	59 d
	Leaves	47 a	55 b	47 a	32 de	30 de	31 de	40 cd	33 de	40 de
	Rhizomes	0 a	0 a	0 a	0 a	1 a	1 a	1 a	2 a	2 a
Merion Kentucky bluegrass	Roots	18 a	16 a	17 a	14 ab	16 a	9 c	7 c	10 bc	8 c
	Stems	20 a	22 a	50 b	50 b	53 b	51 b	51 b	51 b	47 bc
	Leaves	62 a	62 a	33 de	35 cd	30 e	36 cd	38 cd	37 cd	40 c
	Rhizomes	0 a	0 a	0 a	1 a	1 a	4 b	4 b	3 b	5 c

* Values represent the percent radioactivity based on total ^{14}C-incorporation per plant.

**Means within rows (across) with common letters are not significantly different at the 5% level by Duncan's Multiple Range Test.