GE 9816-124

Executive Summary

UNIVERSITY OF GEORGIA **October 2000**

SEASHORE PASPALUM ECOTYPE TOLERANCE TO ROOT LIMITING SOIL STRESSES AND TRAFFIC STRESSES

2000 Research Grant: $25,000
(Third Year of Support)

Dr. Robert N. Carrow
Principal Investigator

Root Limiting Soil Stresses Component

The breeding/genetics paradigm of Dr. R.R. Duncan's program for seashore paspalum (SP) (Paspalum vaginatum) is to systematically determine ecotype tolerance to important stresses. Of particular interest is genetic-based resistance to soil chemical and physical factors that limit root development/longevity. In this project, SP ecotypes are screened for root responses to 4 of 6 edaphic factors that limit rooting. This multiple stress approach provides important information for SP resistance to individual and multiple soil stresses and is highly effective in identifying SP ecotypes with high nutrient uptake efficiency and drought resistance via possessing a deep, extensive, viable root system. Root tolerance assessment to the major edaphic stresses has been a "missing ingredient" in almost all breeding programs targeted to improve drought resistance, water-use efficiency, or nutrient-use efficiency.

Studies 1 and 2 focus on root-limiting soil stresses often found on non-salt affected sites (as well as on salt affected sites). Quantifying superior performance of seashore paspalums on non-salt affected sites is essential for turf managers who desire to use this species on recreational areas that do not have a salt problem (i.e., the initial objective of the paspalum program has been to develop ecotypes for salt-affected areas but this species has characteristics that make it a viable choice for non-salt affected soils). The four studies under this project are:

Study 1. Evaluation of Seashore Paspalum Ecotypes and Selected Grasses To The Acid Soil Complex.

Eighty-four seashore paspalum ecotypes and three control grasses (common bermudagrass, Tifway bermudagrass, and Meyer zoysiagrass) were plugged (3.5 in. dia. x 3 in. deep; A = 0.07 ft.^{2}) on 30 June 1998 into two adjacent sites at 4.5 feet centers. Both sites were a Cecil kaolinitic clay soil with 23% clay (A horizon) and 45% (B horizon). Site A was at pH 4.2 to create the acid soil complex stress which consists of Al/Mn toxicities and potential deficiencies of Mg, K, Ca, and P. Site B was at pH 6.5. Both sites imposed the root stresses of high soil strength in a non-cracking soil, drought stress, and high soil temperatures. Study 1 was completed 26 July 1999 and results reported in the 1999 USGA report.

Study 2. Fairway Type Seashore Paspalums: Rooting, Water Use, Drought Resistance.

Nine seashore paspalum ecotypes and Tifway bermudagrass were established 16 July 1998 using a limited quantity of stolons due to availability. Turf coverage, quality, color, and shoot density ratings were initiated in 1999 and continued through 2000. Rooting and water use (ET) date were also obtained and are under analysis. All grasses were subjected to period dry-down periods of 7 to 18 days to induce drought stress. Leaf firing (chlorosis/ yellowing and leaf tissue desiccation induced by drought stress) was used to assess overall drought resistance.

For the 9 seashore paspalums the ranges in shoot performance averaged across both years were: 5.8 to 7.4 for turf quality (9.0 = ideal); 6.1 to 7.5 shoot density; and 6.1 to 7.5 color; while Tifway bermudagrass averaged 7.0, 7.1, and 7.3, respectively. Out of a total of 34 shoot performance measurements, grasses ranking in the top (best) statistical group the most frequently were: Sea Isle 1 (34), Temple 1 (31), TCR 6 (28), and Tifway bermudagrass (27), while Adalayd (5) and AP 1 (3) ranked lowest.

During dry-down periods to induce drought stress, grasses exhibiting the least leaf firing averaged over all dry-down periods were: Temple 1 (2% of leaves showing leaf firing); Sea Isle 1 (3%), and Tifway bermudagrass (12%); while the highest leaf firing occured on Q36313 (33%) and Adalayd (27%).

These data illustrate: a) certain seashore paspalums exhibit similar shoot quality traits to hybrid bermudagrasses; b) some seashore paspalums have equal or better drought resistance than Tifway bermudagrass [research by Huang, Duncan, and Carrow. 1997, Crop Science 37(6): 1858-1863 also demonstrated similar results]; and c) seashore paspalum can perform at high quality and drought resistance levels on non-salt affected sites.

Study 3. Traffic Tolerance of Seashore Paspalum Ecotypes.

Twenty nine seashore paspalums, three bermudagrasses (TifSport, TifEagle, Tifway), and Meyer Zoysiagrass were stolonized on 12 August 1999. In 2000, these will be assessed for tolerance to: (a) wear, and (b) traffic-wear plus soil compaction. Data are under analysis.

Study 4. Salinity and Salinity + Drought Tolerances of Seashore Paspalum Ecotypes.

This study will involve 34 seashore paspalums to be screened for salinity tolerance $\pm$ drought stress with salinity up to seawater (EC_w = 54 d Sm^{-1}) and applied by overhead irrigation. The greenhouse facility is completed and the study will be conducted starting in January 2001. The study was delayed due to lack of technician support from a frozen open position and another technician with long-term health problem.

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Root Limiting Soil Stresses and Drought Resistance of Seashore Paspalums

The breeding/ genetics paradigm of Dr. R.R. Duncan's program for seashore paspalum (SP) (Paspalum vaginatum) is to systematically determine ecotype tolerance to important stresses. Of particular interest is genetic-based resistance to soil chemical and physical factors that limit root development/ longevity. For grasses, these are: 1) high soil strength, 2) soil drought where soil drying causes death of roots that varies considerably with ecotypes within a species, 3) high soil salinity limiting root growth through physiological drought and specific ion toxicity, 4) acid soil complex stress (Al/ Mn toxicities, nutrient deficiencies), which is common on kaolinitic and Fe/ Al oxide soils, 5) low soil oxygen, and 6) high air and soil temperatures, especially for cool-season species.

In this project, SP ecotypes are screened for root responses to four of the six edaphic factors that limit rooting. This multiple stress approach provides important information for SP resistance to individual and multiple soil stresses and is highly effective in identifying SP ecotypes with high nutrient uptake efficiency and drought resistance via possessing a deep, extensive, viable root system. Root tolerance assessment to the major edaphic stresses has been a "missing ingredient" in almost all breeding programs targeted to improve drought resistance, water-use efficiency, or nutrient-use efficiency. The four studies included in this project are:

Study 1. Evaluation of Seashore Paspalum Ecotypes and Selected Grasses To The Acid Soil Complex and Multiple Root Limiting Soil Stresses.

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Study 2. Fairway Type Seashore Paspalums: Rooting, Water Use, Drought Resistance.

Nine seashore paspalum ecotypes and Tifway bermudagrass were established 16 July 1998 using a limited quantity of stolons due to availability.

The November 1999 report contained the 1998-1999 turfgrass quality, color, shoot density, and turfgrass coverage data. Tables 2 through 5 contain 2000 rating. Table 1 summaries turfgrass shoot performance across all years, while Table 2 summaries leaf firing in response to soil drought over three dry-down periods.

Rooting by soil depth (1 to 12 inches; 12 to 24 inches) data, water extraction data; and total water use (ET, evapotranspiration) during dry-down data are to be analyzed.

As demonstrated by the leaf firing data and shoot performance data that were obtained over well-irrigated and dry-down situations in 1999 and 2000, Sea Isle 1 and Temple 1 seashore paspalums exhibited equal (quality, density, leaf firing) or better (color) shoot performance than Tifway bermudagrass. An interesting feature of seashore paspalums observed during dry-down periods was that 1 to 3 days prior to leaf desiccation paspalums would exhibit a degree of leaf chlorosis (similar to what centipedegrass does but more rapidly and distinctly). This would be an excellent visual indicator for irrigation scheduling.

Study 3. Traffic Tolerance of Seashore Paspalum Ecotypes.

Twenty-nine seashore paspalums, three bermudagrasses (TifSport, TifEagle, Tifway), and Meyer Zoysiagrass were stolonized on 12 August 1999.

Wear and traffic (wear + soil compaction) treatments were applied in 2000, data were obtained, and statistical analysis is in progress.

Study 4. Salinity and Salinity + Drought Tolerances of Seashore Paspalum Ecotypes.

This study will involve 34 seashore paspalums to be screened for salinity tolerance $\pm$ drought stress with salinity up to seawater (EC_w = 54 d Sm^{-1}) and applied by overhead irrigation. The greenhouse facility is completed and the study will be conducted starting in January 2001. This study was initially scheduled to start in winter 2000 but has been delayed due to lack of state supported technical staff (one open position; one on medical leave).

Table 1. Summary of turfgrass shoot performance over 1999 to 2000

Grass	Average 1999 and 2000			Times in the Top (best) Statistical Group			
	Turf Quality	Turf Color	Turf Density	Quality	Color	Density	Total
	----------9 = ideal----------			12=best	12=best	10=best	34=best
Adalayd	6.0	6.5	6.2	1	3	1	5
AP 1	5.8	5.9	6.1	0	2	1	3
Sea Isle 1	7.4a	7.5a	7.5a	12	12	10	34
HYB 7	6.8	7.2	7.0	7	9	7	23
Q36313	6.3	6.7	6.7	3	4	3	10
Taliaferro	6.5	7.1	6.6	2	7	2	11
TCR 1	6.6	7.1	6.8	4	8	4	16
TCR 6	6.9	7.3a	7.0	9	11	8	28
Temple 1	7.2a	7.5a	7.3a	11	11	9	31
Tifway bermuda	7.0a	7.1	7.3a	9	8	10	27
LSD (.05)=	.45	.28	.37	-	-	-	-
F-test =	**	**	**	-	-	-	-
CV (%)	5	4	5	-	-	-	-

***, **, † Significant difference at probability level 0.01, 0.05, and 0.10, respectively.
‡ The letter "a" denotes the top (best) statistical group.

Table 2. Leaf firing and turf cover ratings in 2000 on 9 seashore paspalums and 1 bermudagrass (DAI = days after irrigation).

Grass	Turf Coverage 5 May	Leaf Firing ≠, §, # 18 July (14 DAI)	26 July (7 DAI)	18 Aug (18 DAI)	Average
	%	----------%----------			
Adalayd	93	29	7a	44	27
AP 1	92	25	3a	45	24
Sea Isle 1	100a	6a	1a	2a	3a
HYB 7	96a	33	4a	18a	18
Q36313	88	48	12	50	33
Taliaferro	91	22	<1a	26	16
TCR 1	91	43	11	29	28
TCR 6	97a	17a	2a	8a	9a
Temple 1	98a	1a	0a	4a	2a
Tifway bermuda	100a	13a	2a	21	12a
LSD (.05) =	6	16	10	17	13
F-test =	**	*	†	**	*
CV (%)	4	60	57	49	52

***, **, † Significant difference at probability level 0.01, 0.05, and 0.10, respectively.
‡ The letter "a" denotes the top (best) statistical group.
§ Dry-down periods: 5 July to 18 July; 20 July to 28 July; and 1 August to 18 August.
# Leaf firing: yellowing and/ or leaf desiccation resulting from soil dry-down after an irrigation event.

Table 3. Turf quality ratings in 2000 of 9 seashore paspalum ecotypes and 1 bermudagrass.

	Turf Quality ‡, §							
Grass	15 May	5 July	18 July	26 July	8 Aug	18 Aug	12 Sep	24 Oct
	9=ideal							
Adalayd	6.8a	7.2	6.4	6.4	6.3	5.7	5.3	6.4
AP 1	6.6	7.1	6.4	6.7	6.6	5.6	5.7	6.9
Sea Isle 1	7.3a	7.8a	7.5a	7.6a	7.5a	7.5a	7.8a	7.9a
HYB 7	7.0a	7.4	6.7	7.0a	7.3a	6.7	7.3a	7.1
Q36313	6.1	7.3	6.1	6.0	6.5	5.4	7.1a	6.3
Taliaferro	6.8a	7.4	6.5	6.8	7.0a	6.6	6.7	7.1
TCR 1	6.9a	7.4	6.2	6.3	6.8	6.2	7.0a	7.1
TCR 6	7.0a	7.4	7.0a	7.2a	7.3a	7.1a	7.4a	7.4
Temple 1	7.4a	7.5a	7.6a	7.5a	7.3a	7.3a	7.4a	7.8a
Tifway bermuda	7.4a	7.3	6.9a	7.4a	7.3a	6.8	7.2a	7.3
LSD (.05) =	.63	.35	.72	.64	.56	.66	.85	.47
F-test =	**	†	**	**	**	**	**	**
CV (%)	6	3	7	6	5	7	8	4

***, **, † Significant difference at probability level 0.01, 0.05, and 0.10, respectively

‡ The letter "a" denotes the top (best) statistical group.

§ Dry-down periods: 5 July to 18 July; 20 July to 28 July; 1 August to 18 August.

Table 4. Turf color ratings in 2000 of 9 seashore paspalums and 1 bermudagrass.

	Turf Color ‡, §							
Grass	5 May	7 July	18 July	26 July	8 Aug	18 Aug	12 Sept	24 Oct
	---------- 9= dark green; 1= no green----------							
Adalayd	7.5a	7.0	6.4	6.2	6.3	5.6	5.4	6.4
AP 1	7.2	7.3	6.7a	6.7	6.7	5.8	6.1	7.3
Sea Isle 1	7.5a	7.8a	7.4a	7.6a	7.4a	7.5a	7.6a	7.7a
HYB 7	7.5a	7.5a	6.8a	7.2a	7.3a	6.8a	7.4a	7.2
Q36313	7.0	7.5a	6.1	6.3	6.7	5.4	7.2a	6.5
Taliaferro	7.4a	7.5a	6.6	6.8	7.1a	6.6	6.9a	7.3
TCR 1	7.5a	7.5a	6.3	6.8	7.2a	6.2	7.3a	7.4
TCR 6	7.3	7.5a	7.0a	7.2a	7.4a	7.3a	7.5a	7.5a
Temple 1	7.8a	7.7a	7.5a	7.5a	7.3a	7.3a	7.5a	7.8a
Tifway bermuda	7.4a	7.4	7.0a	7.4a	7.5a	7.1a	6.9a	7.3
LSD (.05) =	.41	.37	.80	.54	.64	.70	.90	.32
F-test =	*	†	*	**	*	**	**	**
CV (%)	4	3	8	5	6	7	9	3

***, **, † Significant difference at probability level 0.01, 0.05, and 0.10, respectively
‡ The letter "a" denotes the top (best) statistical group.
§ Dry-down periods: 5-18 July; 20-28 July; 1-18 August.

Table 5. Turfgrass shoot density in 2000 for 9 seashore paspalum ecotypes and 1 bermudagrass.

	Turf Density ‡, §					
Grass	5 May	7 July	26 July	8 Aug	12 Sept	24 Oct
	---------- 9= ideal ----------					
Adalayd	7.0	7.4a	6.8	6.7	6.0	6.5
AP 1	6.7	7.2a	7.0	6.9	6.3	7.0
Sea Isle 1	7.4a	7.8a	7.7a	7.6a	7.8a	7.9a
HYB 7	7.1a	7.4a	7.2	7.4a	7.4a	7.3
Q36313	6.5	7.4a	6.6	6.8	7.2a	6.5
Taliaferro	6.9	7.4a	7.0	7.2a	7.1	7.2
TCR 1	7.0	7.5a	6.7	7.0	7.1	7.2
TCR 6	7.0	7.4a	7.3a	7.3a	7.4a	7.5a
Temple 1	7.6a	7.6a	7.6a	7.3a	7.5a	7.9a
Tifway bermuda	7.5a	7.3a	7.5a	7.4a	7.3a	7.5a
LSD (.05) =	.56	.35	.37	.44	.67	.44
F-test =	**	.15	**	**	**	**
CV (%)	5	3	4	4	6	4

***, **, † Significant difference at probability level 0.01, 0.05, and 0.10, respectively.
‡ The letter "a" denotes the top (best) statistical group.
§ Dry-down periods: 5-18 July; 20-28 July; 1-18 August.

ACTIVITIES RELATED TO TOPICS IN THIS PROJECT

The following activities are related to topics addressed within the above studies but none of these activities involved direct or indirect (i.e., though Dr. Duncan's project) support from USGA. USGA support for my contributions to the overall seashore paspalum efforts from 1993-2000 consists solely of the monies noted in this project. Any items that are a part of Dr. Duncan's project did not include monies to be allocated to me since the USGA limits on dollar support per year did not allow for this. Thus, the contributions made by me (co-author of 2 books; co-author of web-site; co-presenter of 2-day workshop; co-advisor to two graduate student; numerous publications; collaborator on paspalum releases) were not supported by the USGA.

PRESENTATIONS:

2000(5) Australian Millennium Turfgrass Conference, Melbourne, Australia 4-9 June. Two workshops, one plenary talk, two talks.
* Plenary address: Plant Tissue Analysis as a Management Tool
* Managing Sports Field Soils
* Fertilize Efficacy and Mode of Action (2)
* New Developments in Turf Water Issues

2000 Plenary address on USGA Program at the GCSAA Inter. Conference Feb. 2000. New Orleans, LA
* Purchasing New Products and Technologies: an Ethical and Common - Sense Approach.

2000(4) GCSAA Regional Workshop "Soil Physical Problems of Turfgrass Soils"
* Atlanta, GA (Jan)
* Chicago, IL (Jan)
* Valley Forge, PA (Mar)
* Albuquerque, NM (Dec)

2000(2) USGA Regional Turf Conference. 27-29 March, Denver, CO and Salt Lake City, UT.
* Aerification: Choosing What's Best, For Your Situation
-CO
-UT

2000(1) GCSAA Salt-Affected Turfgrass Sites Workshop. Myrtle Beach, NC (Nov.)

2000(1) American Golf/ Norvartis Regional Conference.
* Managing Turfgrass in Salt-Affected Sites

PUBLICATIONS:

* Denotes a publication with the Graduate Student listed as senior author before the Major Professor.

Books Authored or Co-Authored

1. Duncan, R.R. and R.N. Carrow. 2000. Seashore Paspalum: The Environmental Turfgrass. Ann Arbor Press, Chelsea, MI. (281 p.).

2. Carrow, R.N., P.E. Rieke, and D.V. Waddington. 2001. Turfgrass Soil Fertility and Chemical Problems: Assessment and Management. Ann Arbor Press, Chelsea, MI (submitted Sept. 2000) approx. 500 p.).

3. Carrow, R.N. and R.R. Duncan. 2001. Turfgrass Water Conservation Strategies: Science and Practicum. Ann Arbor Press, Chelsea, MI. (Feb 2001).

Book/ Monograph Chapter

1. Duncan, R.R. and R.N. Carrow. 1999. Turfgrass molecular genetic improvement for abiotic/ edaphic stress resistance. In D.L. Sparks (ed.). Adv. In Agron., Acad. Press, NY 67: 233-305.

Journal Articles

*1. Trenholm, L.E., R.N. Carrow, and R.R. Duncan. 1999. Relationship of Multispectral Radiometry Data to Qualitative Data in Turfgrass Research. Crop Sci. 39 (3): 763-769.

*2. Trenholm, L.E., R.R. Duncan, and R.N. Carrow. 1999. Wear Tolerance, Shoot Performance and Spectral Reflectance of Seashore Paspalum and Bermudagrass. Crop Sci. 39 (4): 1147-1152.

3. Johnson, B.J. and R.N. Carrow. 1999. Tolerance of zoysiagrass (Zoysia spp.) cultivars to pre-emergence herbicides. Weeds Tech. 13(4): 706-712.

*4. Trenholm, L.E., R.N. Carrow, and R.R. Duncan. 2000. Mechanisms of wear tolerance in seashore paspalum and bermudagrass. Crop Sci. 40: 1350-1357.

*5. Trenholm, L.E., R.R. Duncan, R.N. Carrow, and G.H. Snyder. 2000. The influence of silica on growth, quality, and wear tolerance of seashore paspalum. Crop Sci. (accepted).

*6. Trenholm, L.E., R.N. Carrow, and R.R. Duncan. 2000. Wear tolerance, growth, and quality of seashore paspalum in response to nitrogen and potassium. Hort. Sci. (accepted).

*7. Lee, G., R.R. Duncan, and R.N. Carrow. 2001. Salinity tolerance of seashore paspalum ecotypes: Physiological responses of shoot growth. Crop Sci. (submitted).

*8. Lee, G., R.N. Carrow, and R.R. Duncan. 2001. Salinity tolerance of seashore paspalum

ecotypes: physiological responses of root, stem, and total growth. Crop Sci. (submitted).

9. Carrow, R.N., R.R. Duncan, J.E. Worley, and R.C. Shearman. 2001. Turfgrass traffic (wear plus soil compaction) simulator: Response of *Paspalum vaginatum* and *Cynodon* spp. Inter. Turf Soc. Res. Journal 9: (submitted).

10. Carrow, R.N., R.R. Duncan, and R.C. Shearman. 2001. Integrating turfgrass science/ management information: Approaches and implications. Inter. Turf Soc. Res. Journal 9: (submitted).

11. Duncan, R.R. and R.N. Carrow. 2001. A stay-green warm season turfgrass-from dream to reality. Inter. Turf Soc. Res. Journal 9: (submitted).

12. Shearman, R.C., R.N. Carrow, L.A. Wit, R.R. Duncan, L.E. Trenholm, and J.E. Worley. 2001. Turfgrass traffic simulators: Response of turfgrass to two types of self-propelled devices simulating wear or traffic stress injury. Inter. Turf Soc. Res. Journal 9: (submitted).

*13. Lee, G.J., R.N. Carrow, and R.R. Duncan. 2001. Criteria for assessing salinity tolerance for halophytic turfgrass. Crop Sci. (ready for submission).

*14. Lee, G.J., R.N. Carrow, R.R. Duncan, M.W. Rieger, and M.A. Eiteman. 2001. Verification of evaluation criteria for salinity tolerance in halpophytic seashore paspalum. Crop Sci. (ready for submission).

*15. Lee, G.J., R.N. Carrow, R.R. Duncan, M.A. Eiteman, and M.W. Rieger. 2001. Salinity effects on water potential, ionic relations, and salinity tolerance of seashore paspalum turfgrass ecotypes. Crop Sci. (ready for submission).

*16. Lee, G.J., R.N. Carrow, R.R. Duncan, M.A. Eiteman, and M.W. Rieger. 2001. Effects of photosynthetic parameters on salinity tolerance fo seashore paspalum turfgrass. Crop Sci. (ready for submission).

*17. Lee, G.J., R.R. Duncan, R.N. Carrow, M.A. Eiteman, and M.W. Rieger. 2001. Organic solutes in salinity tolerance of seashore paspalum turfgrass. Crop Sci. (ready for submission).

18. Carrow, R.N. and R.R. Duncan. Superior drought resistance in tall fescue: Research protocol and field performance. (In preparation for Crop Sci.).

19. Carrow, R.N. Zoysiagrass (Zoysia spp) water use and root/ shoot response under drought stress. Crop Sci. (In preparation).

20. Carrow, R.N. Traffic tolerance of zoysiagrass ecotypes as influenced by nitrogen fertilization. Crop Sci. (In preparation).

Bulletins or Reports († Refereed)

†1. Carrow, R.N. 2000. Strategies for turfgrass water conservation and maintaining quality (Keynote Address). Irr. Aust. 2000 Conf. Proc. Irr. Assoc. of Aust., Melbourne, Aust. p. 543-548. (REFEREED).

2. Carrow, R.N. and R.R. Duncan. 2000. Wastewater use for turfgrass: Potential problems and solutions. Irr. Aust. 2000 Conf. Proc. Irr. Assoc. of Aust., Melbourne, Aust. p. 679-683.

†3. Duncan, R.R. and R.N. Carrow. 2000. Molecular breeding for tolerance to abiotic/ edaphic stresses in forage and turfgrass. (Keynote address). 2nd Inter'l Symposium of Molecular Breeding of Forage Crops 2000 Australia. (accepted) (REFEREED).

4. Carrow, R.N., P. O'Brien, C. Hartwiger, and R.R. Duncan. 2001. Why Do Golf Greens Sometimes Fail? USGA Green Section Record. Special Supplement Issue. (in preparation). Note: *This extensive article will be a complete issue of the USGA Green Section Record published as a supplement (i.e., 2nd issue along with the normal issue). This is only the second time in 37 years the USGA has allowed this approach. We detail 10 reasons for failure of golf course greens, regions in the world where the particular problem may occur and very specific management approaches. Our approach is to address these problems in a in-depth manner, integrating the research of others, and providing specific management information/ options to positively impact golf green management around the globe. This publication goes world-wide to golf courses as one of the two most used trade publications for golf course superintendents.*

Any Other

1. Carrow, R.N., R.R. Duncan, and M. Huck. 1999. Treating the cause, not the symptoms-irrigation water treatment for better infiltration. USGA Green Section Record 37(6): 11-15. Note: *This is the first article of a series of six that will provide a in-depth treatment of water quality issues on turfgrass- others are on seawater irrigation; effluent irrigation; assessing water quality; leaching of salts and B; and treating irrigation water (see 3, 5, 6, 8). Plans are to then bundle them into a soft back booklet on Turfgrass Water Quality. As a result of discussions by Dr. Duncan and I on this need to provide turf managers more in-depth/ specific information and the current lack of outlets for publishing these articles (longer than current trade magazine articles), the USGA is now a) allowing 1 article per issue that would be 2-4X longer than in the past, b) allowing a series into a booklet, and c) allow the publication of a "supplemental issue" on summer bentgrass decline and the reasons greens sometimes fail-only the 2nd time in 37 years they have done this.*

course turf. Golf Course Mgt. 67 (5): 58-60.

3. Duncan, R.R., R.N. Carrow, and M. Huck. 2000. Effective use of seawater irrigation on turfgrass. USGA Green Section Record 38 (1): 11-17. NOTE: *This is the first published article on the use of seawater for turfgrass irrigation.*

4. Duncan, R.R. and R.N. Carrow. 2000. The next generation turf-type tall fescue. Diversity 16 (1-2): 45-46.

5. Huck, M., R.R. Duncan, and R.N. Carrow. 2000. Effluent water: nightmare or dream come true? USGA Green Section Record 38 (2): 15-29. Note: *This is the most extensive article published on use of effluent water on turfgrass.*

6. Duncan, R.R., R.N. Carrow, and M. Huck. 2000. Understanding water quality and guidelines to management. USGA Green Section Record. 38 (5): 14-24.

7. Carrow, R.N. 2000. Purchasing new products and technologies: an ethical and common-sense approach. USGA Green Section Record. 38 (3): 17-20.

8. Carrow, R.N., M. Huck, and R.R. Duncan. 2000. Leaching for salinity management on turfgrass sites. USGA Green Section Record. 38 (6): 15-24. NOTE: *This is the most extensive article published on this topic for turfgrasses.*

9. Lee, G., R.R. Duncan, and R.N. Carrow. 2000. Salinity tolerance of *Paspalum vaginatum* and *Cynodon* spp. Genotypes. Australian Turf Management 2 (3): 30-32.

CREATIVE CONTRIBUTIONS OTHER THAN FORMAL PUBLICATIONS:

2000 Co-author of the "**Seashore Paspalum Web-Site**" with R.R. Duncan at <www.georgiaturf.com> NOTE: *This extensive web-site is an example of (a) how to provide "bullet-point" information, (b) how to integrate web-information and book information so they enhance one another rather than duplicate, and (c) providing comprehensive, interaction information. The web-site is another component of our "Seashore Paspalum Release Program" (includes 2 books; web-site; 2-day workshop; 2 grass releases).*

2000 Co-author of the "**Water Issues**" **web-site** under "Lawn and Turf" on <www.georgiaturf.com>. Includes water conservation and water quality sections. NOTE: *This site will be expanded (using the same approach of bullet points and FAQs as the paspalum web-site) as the water conservation book and water quality booklets are evolved.*

2000 Co-author of the "**Tall Fescue**" **web-site** with Dr. Ron Duncan. To go up in Nov. 2000, on <www.georgiaturf.com>.

2000 Establishment of **cooperative efforts** with the Queensland (Australia) Horticulture Institute and Redlands Research Station as they develop a major turfgrass research and information initiative (i.e., to establish the only turfgrass breeding program in Australia).

Activities to-date in this cooperative effort (which also involves Dr. Duncan):

- Visit to Redlands for meetings with turf industry; Redlands administration, scientists, staff; Queensland government officials of the Dept. of Primary Industries: May 2000.
- Hosted visit by Dr. Don Loch, Lead Scientist and Turf Breeder/ Genetics (from QHI Redlands, Australia) at Georgia Station (Aug. 2000).
- Agreed to be co-supervisor for Ph.D. student at Redlands (i.e., Peter Broomhall). (Oct. 2000).
- Responded to request for potential cooperative agreements between Redlands Research Park and UGA (Oct. 2000) in the areas of:
    1. Faculty, Postdoc, Graduate Student, Undergraduate Student Exchanges
    2. Collaborative Research Programs- especially in turfgrass development and water related issues.
    3. Cooperative seminars, Workshops, Information Package Development, Information Linkages, and Course Offerings.