Forage Yields and Plant Character Correlations in 30 *Digitaria* Selections

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INTRODUCTION

Pangolagrass (*Digitaria decumbens* Stent) is well known to have contributed positively to the grassland agriculture of many tropical and subtropical countries of the world. Serious diseases and pests reported on Pangolagrass pastures (*3,4,5,6,9,21*)[2] justify expanding the introduction of *Digitaria* germ plasm for the purpose of intensifying our search for genotypes which could be used directly as forages or as superior parents in a breeding program. Fortunately, *Digitaria* germ plasm has been increased significantly in Florida, Puerto Rico and in many other countries of the Caribbean largely due to plant exploration in South Africa by A. J. Oakes in 1964 (*7*).

In Puerto Rico, Florida and other locations, detailed studies on the morphology, taxonomy and agronomy of these *Digitarias* have been conducted (*1,2,3,8,12,13,15,17,18,19*); attempts likewise have been made to develop new techniques to produce superior forages through hydridization and selection with better agronomic characteristics than those found in Pangolagrass (*10,11,14,16,20*).

The purpose of the present investigation was to evaluate: (a), 29 different entries of various *Digitaria* spp. in comparison with Pangolagrass for total yield and (b), a series of plant characters, during a period of one year at Río Piedras, Puerto Rico. All possible correlations among yield and three independent variables were computed to study the possibility of utilizing these plant characters as a tool in the selection of superior types.

Correlation coefficients were determined for yield of green forage, dry matter and protein as dependent variables, and ground cover ability, resistance to rust, and resistance to yellow aphid infestation, as independent variables.

MATERIALS AND METHODS

Over 200 *Digitaria* accessions, most of them from the USDA collection (*7*), were space-planted in plots 3 feet by 3 feet. All the grasses were propagated vegetatively after having been released from quarantine.

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[2] Italic numbers in parentheses refer to Literature Cited, p. 61–2.

The species distribution in this nursery was as follows: *D. decumbens* Stent, *D. eriantha* Steud., *D. gazensis* Rendle., *D. longiflora* (Retz) Pers., *D. macroglossa* Henr., *D. milanjiana* (Rendle) Stapf, *D. milanjiana* subsp. *eylesiana* Henr., *D. pentzii* Stent, *D. polevansii* Stent, *D. setivalva* Stent, *D. smutsii* Stent, *D. swasilandensis* Stent, *D. valida* Stent, and *Digitaria* sp. The original field identification of Oakes (7), was used.

All accessions were evaluated using visual ratings for the following plant characters: ground cover ability and/or vigor, growth type (bunch, decumbent, prostrate, etc.), reaction to the attack of rust (*Puccinia oahuensis* Ell and Ev.), and resistance to infestation by the yellow aphid (*Sipha flava* Forbes). The 29 best accessions and Pangolagrass are listed in table 1.

These *Digitarias* were planted on a Vega Alta clay loam, on January, 1966, using a randomized complete block design with four replications. A complete fertilizer, 14-4-10, was applied at a rate of 2,400 pounds per acre per year in six equal applications after each harvest at 60-day intervals. The plot size was 9 feet by 25 feet. A center swath, 42 inches by 25 feet, was weighed and samples from each plot were taken for dry matter and nitrogen determinations. The crude protein content was calculated using the factor 6.25 times N (nitrogen). Prior to each harvest at 60-day intervals, all plots were evaluated using visual ratings of one to nine, nine being the best condition. The plant characters rated were (a) ground cover ability and/or vigor, (b) resistance to rust, and (c) resistance to yellow aphid infestation.

RESULTS AND DISCUSSION

The green forage yields (table 2) ranged from 55,577 pounds per selection 16 to 124,764 pounds per acre per year for selection 5. No significant differences were observed among selections 5, 24, 30, 15, 22, 4, 28 and 14. Most of these grasses were significantly better than the remaining 22 *Digitarias* (5-percent level).

The three dependent variables were green forage (Y_1), dry matter (Y_2) and protein yield (Y_3) per acre per year, respectively, while the independent variables were, ground cover ability and/or vigor (X_1), resistance to the rust attack (X_2) and resistance to yellow aphid infestation (X_3).

All possible interrelationships among yield of green forage and the three independent variables are shown in table 3. Positive significant correlations, although low, were observed between total green forage and two of the independent variables, Y_1X_1, $r = 0.34$ and Y_1X_3, $r = 0.12$. A significant negative correlation was observed between total green forage and resistance to the rust attack, Y_1X_2, $r = -0.16$. The correlation coefficients among these variables for each of the six harvests are also shown in table 3. Positive significant correlations were observed between green forage and ground cover ability in all harvests except the second. The second lowest precipita-

tion was observed during the period previous to the second harvest. In part, this could account for the low, nonsignificant correlation observed between green forage, dry matter and ground cover ability in that harvest

TABLE 1.—*Thirty* **Digitarias** *selected from a space-planted nursery at Río Piedras, P.R., and their plant introduction (P.I.)*[1] *numbers*

Selection number	*Species field identifications*	*Plant introduction number*	
		USDA P.I.	*P.R. P.I.*
1	*D. milanjiana*	299655	6464
2	do.	299695	6427
3	do.	299696	6429
4	*D. decumbens*	—	5125
5	*D. milanjiana*	299699	6543
6	do.	299667	6610
7	*D. milaniiana* subsp. *eylesiana*	299716	6482
8	*D. milanjiana*	299681	6494
9	*D. milanjiana* subsp. *eylesiana*	299713	6613
10	do.	299736	6658
11	do.	299727	6628
12	do.	299703	6378
13	do.	299709	6391
14	do.	299730	6415
15	do.	299731	6416
16	*D. setivalva*	299791	6471
17	do.	299804	6537
18	*D. smutsii*	299808	6373
19	do.	299828	6434
20	*D. milanjiana* subsp. *eyelesiana*	299728	6408
21	*D. decumbens*	299601	6438
22	do.	279651	5124
23	do.	299837	6535
24	*D. eriantha*	—	5277
25	*D. valida*	299875	6433
26	*D. pentzii*	299742	6405
27	do.	299752	6439
28	*D. setivalva*	299892	6402
29	*D. decumbens*	296210	6523
30	do.	111110	—

[1] U.S. Department of Agriculture and Agricultural Experiment Station, University of Puerto Rico, plant introduction numbers.

(tables 3, 4). The highest negative correlations between green forage and rust resistance were obtained during the fourth and fifth harvests which were made during the last part of November 1966 and January 1967, respectively.

During the period of April 1966 to March 1967 a total of 71.71 inches of

TABLE 2.—*Comparison for the total green forage, dry matter and protein yields of 30* **Digitarias**

Selection	*Green forage*	*Selection*	*Dry matter*	*Selection*	*Protein yields*
Number	*Lbs./acre/year*	*Number*	*Lbs./acre/year*	*Number*	*Lbs./acre/year*[1]
5	124,764 a	24	40,484 a	24	2,449 a
24	122,832 a b	23	32,444 b	5	2,255 a b
30	114,277 a c	30	31,657 b c	29	2,081 a c
15	113,792 a c	22	31,597 b c	28	2,071 a c
22	113,513 a c	4	31,522 b c	19	2,031 a c
4	110,711 a c	5	30,676 b d	23	2,016 a c
28	108,321 a d	21	30,263 b e	11, 22	1,956 a d
14	108,114 a d	19	29,307 b e	30	1,897 a e
21	101,343 b e	27	28,212 b f	4	1,857 b e
20	100,704 b e	14	27,674 b g	15	1,847 b e
23	97,394 c f	11	26,868 b g	21	1,767 b f
26	96,911 c f	15	26,594 b g	27, 14	1,757 b f
19	95,965 c g	2	26,455 b g	20	1,752 b f
29	95,840 c g	28	25,907 b h	7, 6	1,688 b g
27	94,431 c g	29	25,832 b h	18	1,643 c g
7	93,177 c g	20	24,961 c i	12	1,553 c g
11	91,634 c h	6	24,702 c i	26	1,513 c g
6	87,801 d i	26	24,379 c j	2	1,508 c g
18	87,367 d j	18	23,931 d j	17	1,488 c g
2	86,705 d j	7	23,816 d j	1	1,469 c g
17	78,491 e k	17	23,020 e k	8	1,394 d g
8	76,137 f l	12	21,700 f k	3	1,384 d g
12	73,863 g l	13	21,028 f k	10	1,359 d g
13	70,138 h l	3	20,511 j k	25	1,329 e g
10	68,834 i l	1	19,136 j k	9	1,205 f g
1	68,186 i l	10	18,703 h k	13	1,170 f g
3	65,259 i l	8	18,529 h k	16	1,090 g
25	64,851 j l	9	17,957 i k		
9	63,666 k l	25	17,026 j k		
16	55,577 l	16	15,841 k		

[1] Means followed by the same letter are not significantly different (0.05 level of probability) by Duncan's multiple range test.

precipitation fell at the Río Piedras Station. The amount of precipitation which occurred during each of the 60-day intervals between harvests of the experiment was as follows:

Intervals	*Inches*	*Harvest number*
April–May 1966	14.05	1
June–July 1966	10.89	2
August–September 1966	17.48	3
October–November 1966	13.57	4
December 1966–January 1967	11.00	5
February–March 1967	4.72	6

A significant, although small, positive correlation was found between total green forage (table 3) and resistance to the yellow aphid infestation. It was in the sixth harvest that the lowest precipitation was recorded. It also was at this time when the highest positive correlation was observed

TABLE 3.—*Correlation coefficients between green forage yields, ground cover ability and/or vigor, resistance to rust attack, and resistance to yellow aphid infestation for 30* **Digitarias**

Green forage	*Ground cover ability and/or vigor* (X_1)	*Resistance to rust attack* (X_2)	*Resistance to yellow aphid infestation* (X_3)
Yield/pounds/acre			
Total for year (Y_1)	0.34*	−0.16*	0.12*
First harvest	0.38*	0.16	0.06
Second "	0.02	−0.11	0.02
Third "	0.18*	−0.04	0.06
Fourth "	0.32*	−0.27*	0.09
Fifth "	0.46*	−0.22*	0.15
Sixth "	0.38*	−0.12	0.28*

* Significant at the 5 percent level.
Df for total green forage/A/year = 716.
Df for green forage, lbs./A/on each of the six harvests (60-day interval) = 116.

TABLE 4.—*Correlation coefficients between dry matter yield, ground cover ability and/or vigor, resistance to rust attack and resistance to yellow aphid infestation for 30* **Digitarias**

Dry matter	*Ground cover ability and/or vigor* (X_1)	*Resistance to rust attack* (X_2)	*Resistance to yellow aphid infestation* (X_3)
Yield/pounds/acre			
Total for year (Y_2)	0.29*	−0.12*	0.10*
First harvest	0.24*	0.09	−0.01
Second "	0.03	−0.02	0.04
Third "	0.16	−0.01	0.07
Fourth "	0.40*	−0.29*	0.20*
Fifth "	0.41*	−0.18*	0.13
Sixth "	0.33*	−0.06	0.23*

* Significant at the 5 percent level.
Df for total dry matter/acre/year = 716.
Df for dry matter, lbs/A on each of the six harvest (60-day interval) = 116.

between green forage and resistance to infestation by the yellow aphid (r = 0.28). Apparently, the *Digitarias* exhibiting less yellow aphid infestation and, hence, more resistance to this insect attack, produce the highest yields, especially during cool dry periods at Río Piedras.

It would appear then that in the breeding and selection of *Digitarias*, in addition to other characters associated with yield, top priority should be

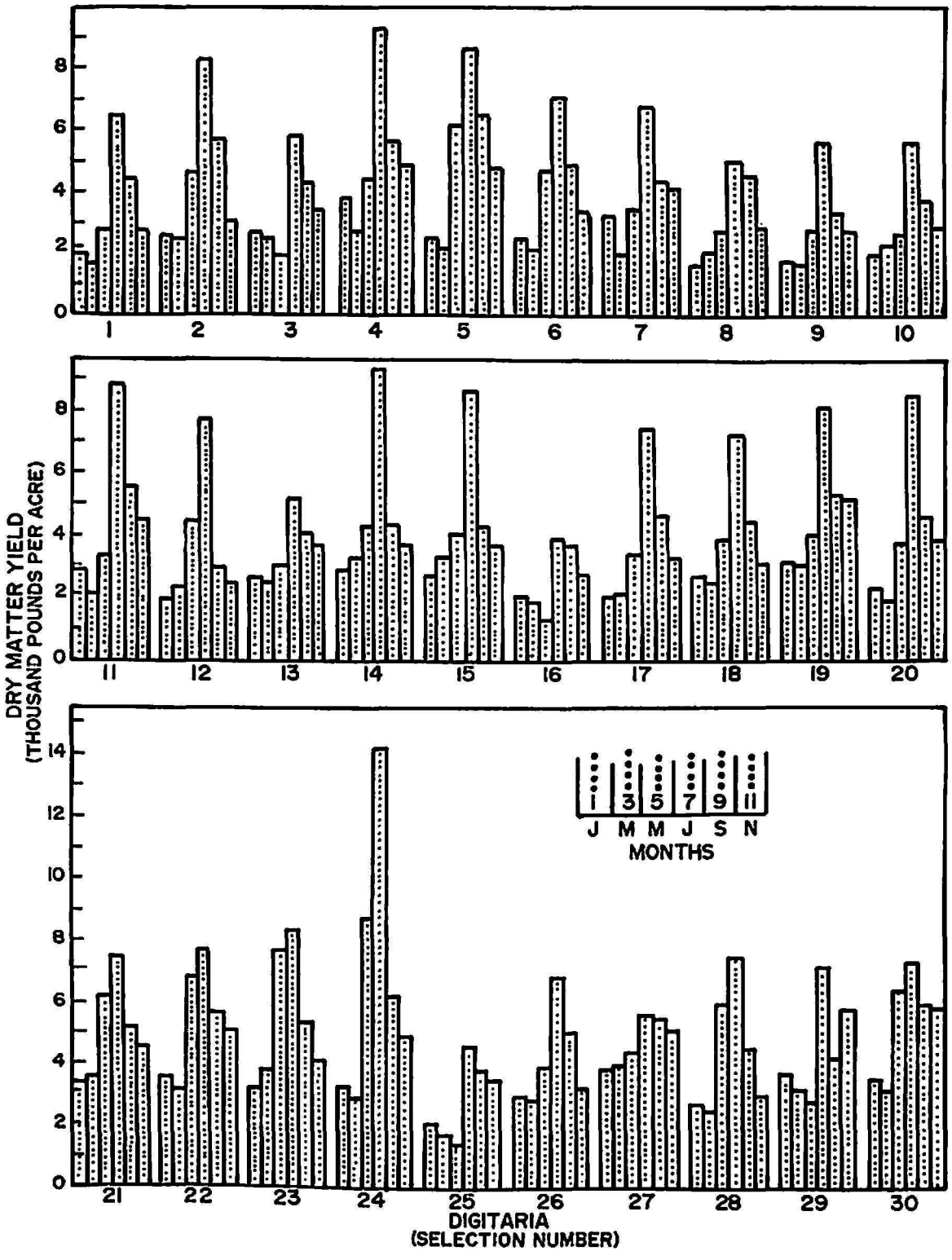

FIG. 1.—Bi-monthly comparison of 30 *Digitarias* during the period of one year at Río Piedras, Puerto Rico.

given to plants showing less degree of yellow aphid infestation. This may result in the selection of plants offering higher resistance to yellow aphid attack. Resistance to rust, on the other hand, may be of less importance.

The data in table 2 and figure 1 show the total dry matter yields and the bi-monthly comparison for each of the 30 *Digitarias*. It can be seen clearly that the yields of all grasses were at their maximum during the July harvest at which selection 24, *D. eriantha*, produced 40,484 pounds of dry matter, the highest yield. This selection proved significantly better than any of the other *Digitarias* tested, including Pangolagrass.

The correlation coefficients between the dry matter yields and the three independent variables of these 30 *Digitarias* are shown in table 4. The

TABLE 5.—*Correlation coefficients between protein yield, ground cover ability and/or vigor, resistance to rust attack and resistance to yellow aphid infestation for 30* **Digitarias**

Protein yields	*Ground cover ability and/or vigor* (X_1)	*Resistance to rust attack* (X_2)	*Resisance to yellow aphid infestation* (X_3)
Yield/pounds/acre			
Total for year (Y_3)	0.25*	−0.14*	0.03
First harvest	0.25*	−0.07	−0.02
Sedond "	−0.01	−0.11	−0.10
Third "	0.06	−0.04	0.01
Fourth "	0.20*	−0.20*	0.05
Fifth "	0.26*	−0.01	0.05
Sixth "	0.26*	0.00	0.17*

* Significant at the 5 percent level.
Df for total protein lbs/A/year = 716.
Df for protein, lbs/A on each of the six harvests (60-day interval) = 116.

partial correlations between the dependent variable (Y) and the independent variables (X) followed a pattern similar to that shown in table 3.

Selection 24, *D. eriantha*, ranked highest for total crude protein (table 2). However, no significant difference ($P = .05$) was observed among the top eight *Digitarias;* their yields ranged from 1,897 to 2,449 pounds of crude protein per acre per year. The correlation coefficients between protein yields and the three independent variables are shown in table 5. The correlation coefficient between total protein (pounds per acre) and ground cover ability and/or vigor, Y_3X_1 ($r = 0.25$), is significant at the 5-percent level. The correlation coefficient between total protein yield and rust resistance, is negative, as in the previous case, and significant at the 5-percent level.

Utilizing the same *Digitarias* and the same field experiment reported in this paper, Liu (*5*) concluded that the causal agent of the disease observed

on these *Digitarias*, and on Pangolagrass, is a variant of *Puccinia oahuensis*. He tentatively identified it as *P. oahuensis* var. *digitaria decumbensis* and concluded that *Digitaria* clones P.I. 6438 and 6535 exhibited a high degree of resistance to Pangola rust.

It may be concluded that rust resistance may not be as important in a breeding program for the development of new *Digitaria* varieties as ground-cover ability and/or vigor and resistance to infestation by the yellow aphid.

SUMMARY

The total green forage, dry matter, and protein yields per acre were determined for 30 *Digitarias* at the Río Piedras Experiment Station for a period of one year.

All grasses were harvested at 60-day intervals; prior to each cutting all plots were evaluated using visual ratings of one to nine, nine being the best condition. The following plant characters: ground cover ability and/or vigor (X_1); resistance to the attack of rust caused by *Puccinia oahuensis* Ell. and Ev. (X_2); and resistance to yellow aphid infestation *Sipha flava* Forbes (X_3), were correlated with total green forage (Y_1), total dry matter (Y_2) and total pounds protein (Y_3).

Significant positive correlations were obtained for Y_1X_1 ($r = 0.34$), Y_1X_3 ($r = 0.12$), Y_2X_1 ($r = 0.29$), Y_2X_3 ($r = 0.10$) and Y_3X_1 ($r = 0.25$). Significant negative correlations were obtained between total green forage and resistance to rust attack, Y_1X_2 ($r = -0.16$); total dry matter yield and resistance to rust attack, Y_2X_2 ($r = -0.12$); and total protein yield and resistance to rust attack Y_3X_2 ($r = -0.14$). When the grasses were rated after each 60-day interval, the more vigorous grasses also were the most susceptible to the rust disease. None of the *Digitarias* exhibited complete resistance to either rust or to yellow aphid attack. The findings show that rust resistance is not as important in a *Digitaria* breeding program as ground cover ability and/or vigor and resistance to yellow aphid infestation.

Dry matter yields ranged from 15,841 to 40,484 pounds per acre yearly. One selection, *D. eriantha* (P.R.P.I. 5277), produced greater yields than the other *Digitarias* at the 5-percent level, including Pangolagrass.

RESUMEN

En la Estación Experimental Agrícola de Río Piedras se determinó el peso verde, peso seco y proteína total por acre de 30 *Digitarias* durante un año.

Todas las yerbas se cosecharon cada 60 días. Antes de cada corte, se evaluaron visualmente todas las parcelas usando una escala de uno al nueve, siendo el nueve la mejor condición. Los siguientes caracteres:

habilidad para cubrir el terreno y/o vigor (X_1); resistencia al ataque de la roya causado por el hongo *Puccinia oahuensis* Ell. and Ev. (X_2); y resistencia a la infestación del áfido amarillo, *Sipha flava* Forbes (X_3), se correlacionaron con el peso verde (Y_1), peso seco (Y_2) y libras de proteína total (Y_3).

Se obtuvieron correlaciones positivas, significativas para $Y_1\ X_1$ (r = 0.34); $Y_1\ X_3$ (r = 0.12); $Y_2\ X_1$ (r = 0.29); $Y_2\ X_3$ (r = 0.10) y $Y_3\ X_1$ (r = 0.25). Se obtuvieron correlaciones negativas, significativas para el peso verde total y resistencia al ataque de la roya, $Y_1\ X_2$ (r = −0.16); el peso seco total y la resistencia al ataque de la roya, $Y_2\ X_2$ (r = −0.12); y la producción de proteína y resistencia al ataque de la roya, $Y_3\ X_2$ (r = −0.14). Cuando se llevó a cabo la evaluación de las yerbas, las más vigorosas también demostraron una tendencia a ser las más susceptibles al ataque de la roya. Ninguna de las *Digitarias* estudiadas demostraron una resistencia total al ataque de la roya o del áfido amarillo.

Se encontró que la resistencia a la roya no es tan importante en un programa de cruzamiento de la *Digitarias* como la habilidad de las yerbas para cubrir el terreno o su vigor de crecimiento, y resistencia a la infestación del áfido amarillo.

La producción de materia seca fluctuó entre 15,841 y 40,484 libras por acre por año. Una selección, *D. eriantha* (P.R.P.I. 5277), superó estadísticamente al 5 por ciento de probabilidad a las demás *Digitarias*, incluyendo la yerba Pangola.

LITERATURE CITED

1. Baskin, J. W., Schank, S. C., and West, S. H., Studies on germination and dormancy of *Digitaria milanjiana* (Rendle) Stapf, from tropical Africa, *Soil Crop Sci. Proc. 27*: 90-96, 1967.
2. Degras, L., Introduction ét étude de varietés de *Digitaria* aux Antilles, *Ann. Amelior. Plantes 18*: 159-69, 1968.
3. Dirven, J. G. P. and Van Hoof, H. A., A destructive disease of Pangolagrass, *Tijdschr. Plziekt 66*: 344-49, 1960.
4. Hodges, E. M., Killinger, G. B., McCaleb, J. E., Ruelke, O. C., Allen, R. J., Jr., Schank, S. C., and Kretschmer, A. E., Jr., Pangolagrass, Agr. Expt. Sta. Univ. Fla. Bull. 718. 31 pp., 1967.
5. Liu, L. J., Occurrence of Rust of Pangolagrass in Puerto Rico, *J. Agri. Univ. P.R. 53*: 132-39, 1969.
6. Nestel, B. L. and Creek, M. J., Pangolagrass, *Herb. Abst. 32*: 1-7, 1962.
7. Oakes, A. J., *Digitaria* collection in South Africa, *Trop. Agr. 42*: 323-31, 1965.
8. Oakes, A. J. and Langford, W. R., Cold tolerance in *Digitaria*, *Agron. J. 59*: 387-88, 1967.
9. Rodríguez, J. P., Rivera-Brenes, L., "El Cultivo de la Yerba Pangola en Puerto Rico", Est. Exp. Agr. Univ. P.R., Bull. 161, Febrero, 1962.
10. Schank, S. C., Improving pangolagrass, *Sunshine State Agr. Res. Rept. 8*: 14-15, 1963.
11. Schank, S. C. and Tan, N. V., Improvement of forage grasses by interspecific

hybridization within the genus *Digitaria*, *Proc. 61st Ann. Conv. Assoc. South. Agr. Workers 62*: 63 p., 1964.

12. Schank, S. C. and Decker, H. F., The Florida Garden of *Digitaria* introductions, *Sunshine State Agr. Res. Rept. 10*: 8-9, April, 1965.
13. Schank, S. C., Decker, H. F., Killinger, G. B., and Allen, R. J., Jr., Agronomic and cytotaxonomic comparisons between *Digitaria decumbens* and *D. pentzii*, *Crop Sci. 6*: 82-3, 1966.
14. Schank, S. C., Duell, R. W., Steenmeijer, H. P., and Decker, H. F., Científicos buscan progenitores de la pangola para superar esterilidad, *La Hacienda 62*: 66-7, June, 1967.
15. Schank, S. C. and Decker, H. F., Cytological investigations in the genus *Digitaria*, *Soil Crop. Sci. Proc. Fla. 27*: 96-101, 1967.
16. Schank, S. C., Breeding grasses for resistance to pangolagrass stunt virus, *Sunshine State Agr. Res. Rept. 13*: 5-7, 1968.
17. Schank, S. C. and Edwardson, J. R., Cytological examination of pangolagrass (*Digitaria decumbens* Stent) infected with stunt virus, *Crop Sci. 8*: 118-19, 1968.
18. Shambulingappa, K. G., Studies on pachytene chromosomes in the genus *Digitaria*, *Genetica 38*: 381-87, 1968.
19. Shambulingappa, K. G., Cytomorphological and Sterility Studies in *Digitaria polevansii*, Stent. *J. Agr. Univ. P.R. 53*: 106-12, 1969.
20. Vega-Luna, M., Schank, S. C., and Ruelke, O. C., Seed-set temperature relationships as measured in a *Digitaria milanjiana* cross, *Soil Crop Sci. Proc. Fla. 27*: 101-06, 1967.
21. Wilson, P. N., Fewkes, D. W., and Emsley, M. G., Note on a Heavy Infestation of Pangolagrass (*Digitaria decumbens* Stent) by the Sugarcane Froghopper (*Aeneolamia varia saccharina Distant*), *Trop. Agr. 39*: 49-51, 1962.