Comparison of Major Agronomic Characters in Guineagrass and Colored Cuineagrass

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Grasses of the genus *Panicum* have been introduced and evaluated for promoting the forage production in summer in warm regions of Japan. In 1960s, Shikoku National Agricultural Experiment Station introduced warm-season grasses including *Panicum* species on systematic basis, and later sporadic introductions of them were made by some universities and research institutes of the Ministry of Agriculture and Forestry. Tropical Agriculture Research Center carried out a search for wild and cultivated forage grasses in tropical Africa in 1972 and 1973, and a large number of valuable native ecotypes and strains of these grasses were collected and introduced.

Of the *Panicum* grasses thus introduced, guineagrass (*P. maximum Jacq.*) and colored guineagrass (*P. coloratum* L.) have come to be recognized as suitable to the high-yielding production by intensive management. These grasses are anticipated to be utilized as perennial grasses in grassland in Okinawa Prefecture, and as summer annual grasses in ordinary field in rotation system with winter annual grasses like Italian ryegrass in the regions from Kyushu to Kanto district. However, their spread is limited at present, because these grasses are unstable in seed germination and seed production, and slow in seedling growth and less competitive to weeds, especially at early growth stage. Therefore, for the wider spread and stable use of these grasses, it is urgently needed to solve these problems by cultural improvements and breeding works.

The author and other workers have worked on the evaluation of ecotypes or strains of the *Panicum* grasses, classification of them by the agronomic characters, and the potentiality of breeding of guineagrass and colored guineagrass which are regarded as the most promising among *Panicum* grasses[1,2,3,5]. In the present paper, the results of investigations on classification and genetic variability of these two grasses will be described.

Classification by principal component analysis and cluster analysis

From the time of the initial introduction to Japan, it was pointed that the taxonomic identification was not correct with some strains of the guineagrass and colored guineagrass. So the materials of the present studies were re-identified based on Hsu (1970) and Bryant (1967) at the starting of the experiments. A total of 69 strains of 7 species of *Panicum* grasses listed in Table 1 were grown by the single-stand method at Nishinasuno, Tochigi in 1973. Thirty four strains of guineagrass and 16 strains of colored guineagrass were included in the materials. Thirty two characters at early growth stage, middle growth stage and maturity stage were measured and subjected to the principal component analysis.

As shown in Table 2, the cumulative contribution from the first to 6th principal components was 0.765, or nearly 80 per cent of whole variation. So, squared distances between strains (d^2) were calculated from the scores of these 6 principal components, and 69 strains were classified based on the squared distances. Strains among which squared distances were

Table 1. ***Panicum*** **species and strains tested at Nishinasuno, Tochigi, in 1973, and their classification into groups and types within group by principal component analysis**

Scientific name	No. of strains		Name of group	Type number within group
P. antidotale Retz.	6		D	1
P. bulbosum H. B. & K.	1		D	5
P. coloratum L.	16			
P. coloratum L.		12	A, B, E, H	2, 3, 4, 7, 9
P. coloratum var. *kabulabula*		1	A	9
P. coloratum var. *makarikariense* Goossens		3	E	2
P. dichotomiflorum Michx.	1		A	14
P. maximum Jacq.	34			
P. maximum Jacq.		30	A, B, C, D, E, F, G	5, 6, 10, 11, 12, 16, 19, 20, 22, 23, 24, 25, 26
P. maximum var. *trichoglume* Eyles.		4	B	12
P. prolutum F. Muell.	1		D	17
P. virgatum L.	5		K	13
P. spp.	5		A, C, G, I, J	8, 9, 15, 18, 21
Total	69		11	26

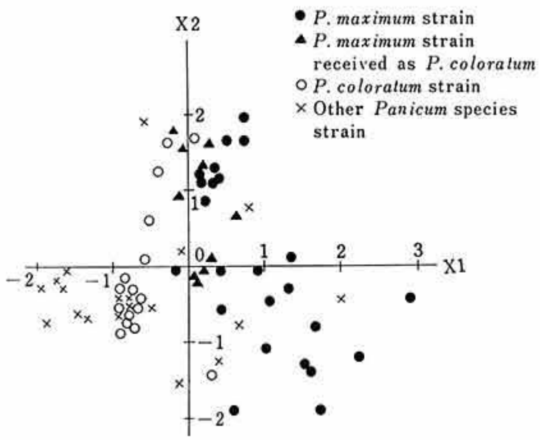


Fig. 1. Scatter diagram of 69 *Panicum* strains in X_1-X_2 plane. X_1 and X_2 indicate the 1st and 2nd principal component, respectively.

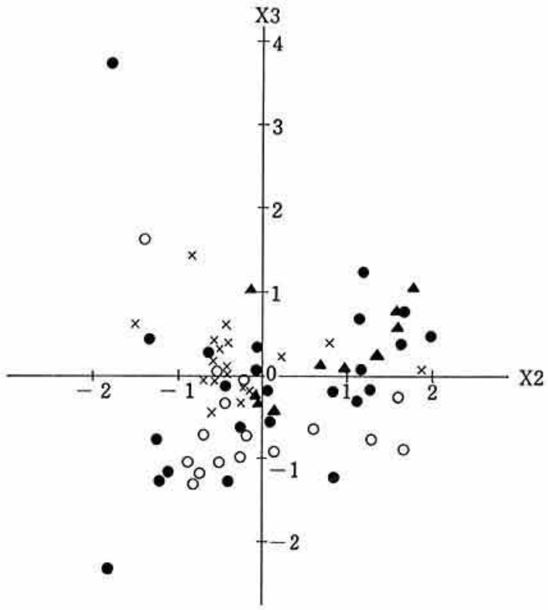


Fig. 2. Scatter diagram of 69 *Panicum* strains in X_2-X_3 plane. X_2 and X_3 indicate the 2nd and 3rd principal components, respectively (Symbols are the same as in Fig. 1.).

small were grouped as types at first. Furthermore, types were classified into groups. As a result, 69 strains of *Panicum* grasses were classified into 26 types of 11 groups (Table 1). Thirty four strains of guineagrass were classified into 13 types of 7 groups, and 16 strains of colored guineagrass into 5 types of 4 groups. Strains of guineagrass and colored guineagrass were grouped into different types, though there were common groups, A, B and E, in these two grasses. As shown in Table 1, guineagrass had so many groups and types

Table 2. Correlation coefficient between character and principal component, eigen value, contribution and cumulative contribution in principal component analysis of 69 *Panicum* strains

Character	Principal component					
	1	2	3	4	5	6
Early growth stage[a]						
Plant height	0.206	0.830	0.057	−0.413	−0.116	−0.042
Number of leaves	0.251	0.721	0.211	−0.389	−0.188	−0.106
Fresh weight	0.173	0.724	0.070	−0.446	−0.059	−0.262
Dry matter content	−0.121	0.460	0.079	−0.374	−0.204	0.434
Middle growth stage[b]						
Plant height	0.599	0.508	0.039	−0.232	0.240	−0.278
Number of tillers	0.682	0.494	0.257	0.036	0.204	−0.015
Leaf breadth	0.759	0.314	−0.007	−0.152	−0.008	−0.017
Number of leaves	0.716	0.493	0.211	0.016	0.217	−0.038
Maturity stage[c]						
Plant height	0.667	−0.332	0.446	0.019	0.091	−0.275
Culm length	0.667	−0.200	0.591	0.093	0.113	−0.141
Panicle length	0.516	0.025	−0.611	0.205	0.263	−0.096
Flag leaf length	0.303	−0.394	−0.594	−0.032	0.050	−0.163
Flag leaf breadth	0.789	−0.242	−0.380	−0.006	−0.177	−0.010
Leaf length	0.771	−0.280	−0.442	−0.114	−0.020	0.042
Leaf breadth	0.872	−0.174	−0.129	−0.038	−0.221	0.155
Number of panicle branches	0.792	0.143	−0.097	0.187	−0.257	0.373
Culm diameter	0.795	−0.165	−0.336	−0.083	−0.131	−0.050
Fresh weight	0.921	−0.102	−0.047	−0.032	−0.006	0.081
Number of tillers	0.193	−0.214	0.641	0.481	−0.183	−0.046
Number of panicles	0.301	0.432	0.428	0.212	−0.269	0.084
Dry matter content	−0.315	−0.298	0.192	−0.391	−0.173	0.145
Plant type[d]	0.493	−0.173	0.580	0.267	0.083	−0.040
Natural plant height[e]	0.667	0.329	−0.315	0.158	−0.216	−0.012
First panicle emergence date	0.485	−0.651	0.293	−0.384	−0.157	−0.042
Heading date	0.462	−0.722	0.257	−0.350	−0.132	−0.025
Full heading date	0.456	−0.721	0.289	−0.337	−0.086	−0.040
Infloresence type[f]	0.597	0.338	−0.016	0.358	0.000	0.310
Panicle branches density[g]	0.196	0.164	−0.131	0.510	−0.605	0.020
Grains density[h]	−0.023	0.237	0.144	0.554	0.061	−0.371
Hairiness of sheath[i]	0.362	0.085	0.030	−0.019	0.681	0.305
Hairiness of leaf blade[j]	0.222	−0.128	0.239	0.037	0.350	0.646
Color of mid-rib[k]	0.542	−0.167	−0.280	0.032	0.252	−0.190
Eigen value	9.853	5.503	3.410	2.461	1.762	1.475
Contribution	0.307	0.171	0.106	0.076	0.055	0.046
Cumulative contribution	0.307	0.479	0.586	0.663	0.718	0.764

a) 32 days after sowing, b) 65 days after sowing, c) 15 days after full heading date, d) 1=erect ~4=prostrate, e) Plant height in natural stand, f) Number of panicle branches from base, 1=one, 2=two, 3=three, 4=four or more, g) Number of panicle branches per panicle length, 1=sparse, 2=medium, 3=dense, h) Number of flowlets per panicle branch length, 1=sparse ~4=dense, i), j) 1=glabrous, 2=hairy, 3=very hairy, k) 1=green, 2=green (translucent), 3=one half length of mid-rib is green (translucent), while another half is white. 4=white.

in number than colored guineagrass. It meant that the former had wider variation than the latter. This fact was also supported by the scatter diagrams of strains illustrated in Figs. 1 and 2. On the both diagrams, the strains of guineagrass distributed in wider ranges than those of colored guineagrass with three axes or principal components. Cluster analysis[3] using the same 32 characters of 69 strains mentioned above indicated that guineagrass had wider variation than colored guineagrass judged from the number and mode of combinations of clusters.

Variations and covariations in major agronomic characters in guineagrass and colored guineagrass

In either principal component analysis or cluster analysis, individual characters observed were integrated to compound characters like principal components, so the variations and covariations of individual characters were not analysed in the both analyses. Therefore, 16 characters which were highly correlated with the first, second and third principal components, and closely related to forage and seed yield, early growth, and maturity were selected. Intra-species means (average value of strain means within species), ranges and coefficients of variation (C.V.) were calculated in guineagrass and colored guineagrass as indices of intra-species variations (Table 3).

As to the characters related to forage yield, guineagrass showed greater means for plant height, culm length and diameter, leaf length and breadth than those of colored guineagrass. The mean of fresh weight was as great as 4 times that of colored guineagrass. Ranges and C.V.s of these characters suggested greater variations in guineagrass.

With plant height at early growth stage which was an important character in the competition against weeds, guineagrass was

Table 3. Means, ranges and C. V. s of strain means of 16 characters of *P. maximum* and *P. coloratum*

Character	*P. maximum*			*P. coloratum*		
	Mean	Range	C. V.	Mean	Range	C. V.
Early growth stage			%			%
1. Plant height (cm)	11.42	3.65–23.31	46.05	8.15	3.37–19.21	64.01
Maturity stage						
2. Plant height (cm)	155.75	110.7–339.3	29.31	125.68	111.3–162.9	10.54
3. Culm length (cm)	148.77	108.6–311.1	25.73	102.29	85.6–165.5	18.96
4. Panicle length (cm)	34.10	17.4–55.6	23.78	32.78	28.7–37.6	6.89
5. Flag leaf length (cm)	27.33	12.4–94.9	69.74	35.90	30.5–38.9	6.89
6. Flag leaf breadth (cm)	1.60	0.63–4.27	50.00	1.05	0.80–1.19	10.17
7. Leaf length (cm)	49.52	22.1–101.3	43.69	39.60	34.6–43.3	6.84
8. Leaf breadth (cm)	1.96	1.35–3.60	29.08	1.10	0.91–1.20	6.99
9. Number of panicle branches	39.37	17.1–61.9	23.13	17.11	12.8–27.2	24.02
10. Culm diameter (cm)	0.48	0.31–0.84	29.16	0.39	0.35–0.45	7.87
11. Fresh weight (g)	1292.20	634.5–3333.5	48.15	392.40	136.3–1012.0	67.88
12. Number of tillers	79.92	34.8–237.2	47.40	54.63	28.9–151.6	61.32
13. Number of panicles	36.87	8.0–74.9	43.66	22.45	7.3–57.9	64.85
14. Plant type	2.29	2–4	22.70	1.50	1–3	48.66
15. Natural plant height (cm)	115.78	61.1–151.7	18.48	96.61	80.3–113.6	9.51
16. First panicle emergence date[1)]	28.08	4–121	21.62	15.25	−1–67	18.72

1) Days after July 31.

superior in its mean, although both grasses showed great ranges and C.V.s. As to the characters related to seed yield, guineagrass was found to have greater means and variations for panicle number, panicle length, and number of panicle branches.

With tropical grasses, forage quality is also required to be improved by breeding works. The digestibility which is considered to be one of the most important characters in forage quality was measured with 69 strains listed above[7]. Dry matter samples were taken at 15 days after full heading date, excepting extremely late-maturing strains as fall panicum (*P. dichotomiflorum* Michx.) and some of guineagrass sampled before full heading date. The dry matter digestibility was measured by the two-step-cellulase method (cellulase 0.5%, 5 hrs). As demonstrated in Fig. 3, fall panicum and blue panic (*P. antidotale* Retz.) showed high digestibility. Although the digestibility of guineagrass was rather lower than that of colored guineagrass in general, some strains of guineagrass were found out to be high.

From the comparisons of important agronomic characters between guineagrass and colored guineagrass mentioned so far, it can be concluded that guineagrass does offer the higher potentiality of breeding by strain selections.

In considering the breeding potentiality, the correlations between characters are important. The correlation coefficients among the 16 characters are graphically shown in Fig. 4. In guineagrass, there were high positive correlations between each characters related to forage yield. As to the correlations to other agronomically important characters, only a few cases of undesirable correlation were found in guineagrass: between first panicle emergence date and fresh weight ($r=0.699^{**}$) or plant height at early growth stage ($r=-0.568^{**}$). On the contrary, colored guineagrass is different from guineagrass in that only a few cases of positive correlation were found between characters related to forage yield. But an undesirable correlation between first panicle emergence date and plant height at early growth stage ($r=-0.522^{**}$) was found like in guineagrass.

As colored guineagrass performs sexual reproduction, it is possible to expand variations and break down undesirable correlations by hybridizations and recombination in breeding. On the other hand, with guineagrass which performs apomixis, the selection of excellent strains can be made efficiently by taking

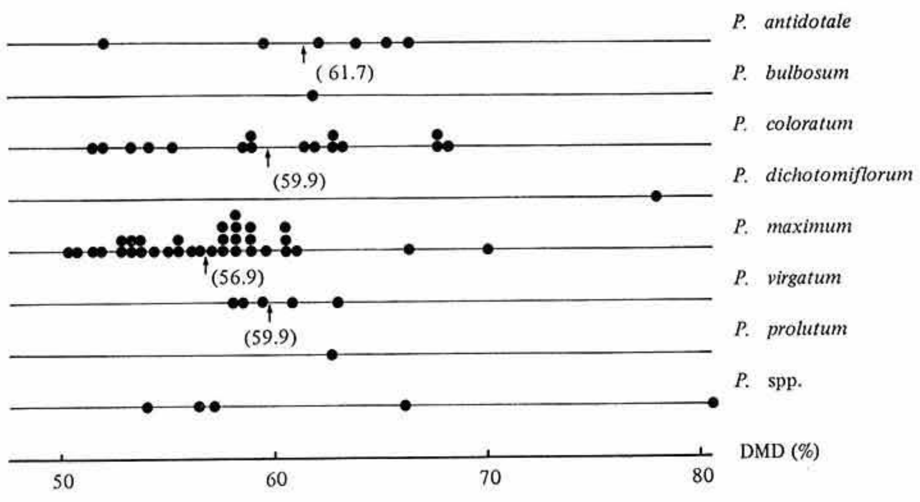
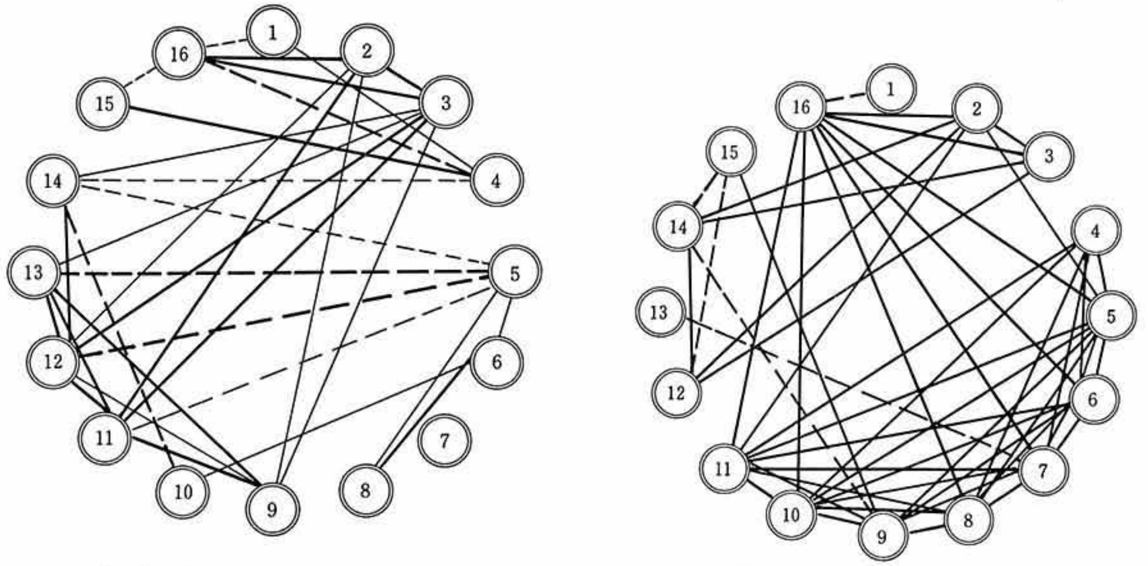


Fig. 3. *In vitro* dry matter digestibility (IVDMD) in 69 strains of *Panicum*. (Nakashima, K., unpublished)
Note: ↑ indicates species mean



P. coloratum *P. maximum*

Fig. 4. Schematic diagrams of correlations among 16 characters in *P. maximum* and *P. coloratum* (Character code numbers are the same as indicated in Table 3.
Notes: —— significant at 1% level, positive; ---- significant at 1% level, negative; —— significant at 5% level, positive; ---- significat at 5% level, negative).

advantage of lack of undesirable correlations and wider ranges of useful variations. However, the breeding in this direction may have a limitation. So it is necessary to find out rare plants with sexual reproduction and utilize them in breeding.

Further breeding program of guineagrass

A large number of guineagrass ecotypes and strains were collected and introduced to Japan from tropical Africa in 1972 and 1973, and it was shown that these African collections and introductions included so many valuable strains which had never been introduced before, and they had tremendous variations in agronomically important characters[4]. Since the introduction of these strains, a search for sexual reproductive plants has been carried out with them. Up to now, several sexual plants were successfully found out[6]. When genetic variations are expanded not only by taking advantage of existing variations with apomictic plants but also by hybridization and recombination using sexual reproductive plants and fixation through crossing with other apomictic suitable plants, desirable genotypes can efficiently be selected. In the near future, it is expected that breeding of guineagrass would be well advanced on this line.

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