Fatty acid composition of neutral lipids in seed grains of *Panicum miliaceum* L.

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木俣美樹男・川村達郎・前野朋之・遠藤節子（2007）キビ種子に含まれる中性脂質の脂肪酸組成。民族植物学ノオト　2：8－13。キビ４７地方品種の種子内に含まれる中性脂肪の脂肪酸組成をガスクロマトグラフィにより定量分析した。穀粒に対する総脂質含量は 3.2～6.7 重量%、総脂質に対する中性脂質含量は 72.2～94.7 重量%の変異幅を示した。総脂質はモチ性品種（平均 5%）、中性脂質はウルチ性品種（平均 89.4%）においてそれぞれ若干高い傾向が認められたが、統計的有意差はなかった。中性脂質の脂肪酸組成は、最も含量の多いリノール酸はモチ性品種（平均 62.7%）で、次に含量が多いオレイン酸はウルチ性品種（平均 22.8%）で高い傾向が示され、パルミチン酸は中間性品種（平均 12.5%）で高い含量と幅広い変異を示したが、これらにも統計的有意差はなかった。一方、微量の脂肪酸であるアラキジン酸、エイコセン酸およびベヘン酸の有無によって、供試品種は４タイプに分類でき、これらの地理的分布には明瞭な偏りが認められ、キビの中央アジア起源と東西両方向への伝播を示唆していた。

Introduction

Many phytochemical components in seed grains have been studied for investigating the phylogenetic differentiation and geographical distribution of domesticated plants in the family Poaceae, for example, starch and phenol compounds in *Setaria italica* (L.) P.Beauv. and *Panicum miliaceum* L. (Kawase and Sakamoto 1982; Kimata and Negishi 2002).

The seed grains of subfamily Panicoideae have a remarkably high lipid content. Similar to amino acid composition, the composition of major fatty acids is the same in the subfamilies in Poaceae (Taira 2003) . Oleic acid and linoleic acid are the major fatty acids, accounting for more than 80% of the total fatty acid content of the seed grains. On the other hand, phylogenetic differences in the minor fatty acid composition are observed in the subfamilies of Poaceae (Taira 1989). For example, differences among the Indian, Chinese, Japanese and Javanese forms of *Oryza sativa* L. (Taira et al. 1988) have been observed ; further geographic variations have also been detected with regard to endosperm starch (glutinous or

non-glutinous) among the Eurasian landraces of *S. italica* (Taira 1986).

The authors have examined the fatty acid composition of the seed grains of the following domesticated plants; *Perilla frutescens*, *Linum usitatissimum*, *Amaranthus hypochondriacus*, *A. caudatus* and *Sorghum bicolor* (Endo *et al.* 1993, 1995, 1996). The present paper compares the fatty acid composition with glutinous or non-glutinous properties of the seed grains of *P. miliaceum*.

Materials and Methods

The landraces of the common millet *P. miliaceum* that were used comprised a total of 47 accessions which had been collected throughout Eurasia, including France (1), Spain (1), Romania (2), the former USSR (3), Afghanistan (3), India (3), Nepal (1), China (4), Korea (2) and Japan (26). A weed form from Romania was also used.

Total lipid was extracted from the seed grains by the Folch method. The extract was then divided into 2 parts — neutral lipids and polar lipids. The fatty acid composition of the purified neutral lipids was analyzed by gas chromatography. The mature seed grains were crushed and soaked in a drop of 300 ppm potassium iodide-iodine solution for 10 min. at room temperature. The colour of the powder indicated the glutinous or non-glutinous property of the seed grains: autumn leaf, glutinous; raspberry red, moderately glutinous; and ink blue, non-glutinous.

Results and Discussion

The total lipid content expressed as a percentage of dry weight and the neutral lipid content expressed as a percentage of total lipid content in seed grains of *P. miliaceum* are shown in Table 1. The total lipid content varied from 3.2% to 6.7% in the landraces used. The total lipid content of glutinous landraces tended to be higher than those of medium and non-glutinous landraces. However, these differences were not statistically significant.

Table 2 shows the fatty acid composition of neutral lipids in the seed grains of *P. miliaceum*. The content of oleic acid (18:1) was the highest in non-glutinous landraces among the 3 types of grain starch. The content of palmitic acid (16:0) and stearic acid (18:0) was the highest in the moderate landraces. The content of linoleic acid (18:2) was the highest in glutinous landraces. These differences were not statistically significant. However, statistically significant differences in the fatty acid composition of seed grains were observed in *S. italica* (Taira 1984).

Table 1. Lipid content in seed grains of *Panicum miliaceum*

Glutinous/ non-glutinous	Strain No.	Locality	Total lipid (%) 1)	Neutral lipid (%) 2)
Non-glutinous	PC049	France	4.7	91.7
	PC050	Spain	6.7	90.9
	PC045	Romania	4.2	89.4
	PC046	Romania	3.3	85.8
	PC041	Former USSR	4	89.3
	PC042	Former USSR	4.1	89.8
	PC043	Former USSR	3.5	84
	PC037	Afghanistan	4.3	95.8
	PC039	Afghanistan	4	90.2
	PC040	Afghanistan	4.8	88.3
	PC067	India	4.9	91
	PC339	India	4.8	89.9
	PC488	India	5.6	91.1
	PC067	Nepal	4.9	81.7
	PC316	China	5.3	89.3
	PC169	Korea	4.6	91.9
	Mean		4.60625	89.38125
	sd		0.801926392	3.20043332
(weed)	PC047	Romania	5.1	90.3
Moderate	PC036	China	4.8	83.8
	PC001	Japan	4.6	94.5
	PC002	Japan	3.5	90
	PC003	Japan	4	86.4
	PC005	Japan	4.5	89.9
	PC006	Japan	3.3	91
	PC007	Japan	4.5	80.3
	PC008	Japan	4.8	94.7
	PC010	Japan	4.7	82.9
	PC011	Japan	3.3	87
	PC012	Japan	3.8	85.7
	PC013	Japan	4	81
	PC015	Japan	5.7	90
	PC016	Japan	4.5	85
	PC017	Japan	3.2	89.8
	PC018	Japan	3.6	80.6
	PC019	Japan	3.8	93.5
	PC020	Japan	4.6	81.6
	PC021	Japan	4.8	83.8
	PC026	Japan	4.2	90.5
	PC054	Japan	4.2	86.6
	Mean		4.20952381	87.07619048
	sd		0.61868121	4.443711958
Glutinous	PC052	China	4.6	85.4
	PC053	China	4.8	78.2
	PC033	Korea	6.7	78.9
	PC023	Japan	5.6	72.2
	PC024	Japan	4.7	77
	PC025	Japan	4.8	86.1
	PC031	Japan	6.1	88.9
	PC166	Japan	3.6	81.8
	PC480	Japan	3.8	90.3
	Mean		4.966666667	82.08888889
	sd		0.953356643	5.675766115

1) % of dry weight for a sample, 2) % of neutral lipids for total lipid

Table 2. Fatty acid composition of neutral lipids in seed grains of *Panicum miliaceum*

Glutinous/ non-glutinous	Strain No.	Locality	16:0	18:0	18:1	18:2	18:3	20:0	20:1	22:0
Non-glutinous	PC049	France	9.6	trace	19.8	63.2	1.8	1		1.3
	PC050	Spain	16	2.7	28.3	25.9	0.1	1.6		2.3
	PC045	Romania	12.4	3.3	19.2	53.1	1.3	2		0.7
	PC046	Romania	12	2.7	18	56.7	2	1.4		0.8
	PC041	Former USSR	10.2	trace	21.2	62.4	1.3	1		1
	PC042	Former USSR	8.5	1.7	17.8	66	0.6	0.7		0.4
	PC043	Former USSR	8.3	3.3	19.2	63.3	1.4	1.6		0.5
	PC037	Afghanistan	8.4	0.2	21.1	62.6	1.5	0.9		0.7
	PC039	Afghanistan	9	0.1	19.6	60	1.5	1.2		0.9
	PC040	Afghanistan	10.5	2.5	17.8	50.9	0.5	1.2		2.7
	PC067	India	7.4	0.3	25.2	64.5	1.3	0.8	0.6	
	PC339	India	6.9	1.3	25.5	63.6	1.2	0.6	0.7	
	PC488	India	7	0.6	33.3	55.5	1.1	0.6	0.8	
	PC067	Nepal	7.4	0.3	25.2	64.5	1.3	0.8	0.6	
	PC316	China	7.8	0.9	23.9	63.9	1.2	0.8	0.9	
	PC169	Korea	12.3	1.7	29.9	53.1	0.8	1	1.6	
	Mean		9.60625		22.8125	58.075	1.18125	1.075		
	sd		2.4327116		4.5728649	9.5230313	0.466662	0.3881044		
(weed)	PC047	Romania	12.6	1.7	29.2	53	0.6	1.4	0.9	
Moderate	PC036	China	8.8	trace	18.3	58.8	1.1	0.6		0.8
	PC001	Japan	12	2.8	16.5	65.3	1.7			
	PC002	Japan	16.2	2.1	16.3	60.5	1.7			
	PC003	Japan	10.8	1.3	18.1	63.9	1.9			
	PC005	Japan	10.3	1.3	21.2	64	1.3	0.9	0.6	
	PC006	Japan	11.7	1.3	15.8	67.1	1.6			
	PC007	Japan	11.1	1.6	19.6	60	1.3			
	PC008	Japan	21.6	trace	24.2	48.5	trace	1		0.9
	PC010	Japan	16.9	1.6	16.7	45.7	3.1	0.7	1.4	3.3
	PC011	Japan	11.9	1.5	16.7	65.7	1.6			
	PC012	Japan	10.8	1.2	15.1	68.9	0.8			
	PC013	Japan	13.2	1	15.6	65.1	2.9			
	PC015	Japan	12	3	18.1	63.3	1			
	PC016	Japan	15.7	1.9	17.3	60.5	1.5			
	PC017	Japan	12.4	1.5	16.9	65.8	1.4			
	PC018	Japan	13.5	1.7	19.6	46.4	1	1.3	1.4	2.6
	PC019	Japan	10.8	1.3	15.4	66.6	3.4			
	PC020	Japan	10.1	trace	20.1	64.4	1.2	0.7	0.8	0.9
	PC021	Japan	14.3	1.6	23	64.1	0.4	1	1	7.1
	PC026	Japan	7.8	4.4	28	49.7	1.4	0.9	0.8	
	PC054	Japan	10.1	0.7	20	57.8	1.7	1		1.5
	Mean		12.47619		18.690476	60.57619				
	sd		3.0480134		3.187013	6.8981643				
Glutinous	PC052	China	11	2.4	15.2	58.1	0.3	0.6		0.6
	PC053	China	10.5	2.1	16.6	63.9	0.4	1		0.7
	PC033	Korea	5.9	0.8	24.1	65.2	0.9	0.5	0.8	trace
	PC023	Japan	10.6	trace	19.1	64.2	1.5	0.9	0.8	0.9
	PC024	Japan	12.8	0.4	18.8	63.4	1.7			
	PC025	Japan	10.1	1	19.9	64	1.2	0.8	1.2	0.7
	PC031	Japan	5.8	trace	22.7	59.6	1.7	1.4	1.2	1.3
	PC166	Japan	9.9	1.1	22	60.8	1.4	0.8	0.6	
	PC480	Japan	10.6	1.2	20.5	65.3	1.2	0.7	0.6	
	Mean		9.6888889		19.877778	62.722222	1.1444444			
	sd		2.1961807		2.6889807	2.4325468	0.4878777			

16:0=palmitic acid; 18:0=stearic acid; 18:1=oleic acid; 18:2=linoleic acid; 18:3=linolenic acid; 20:0=arachidic acid; 20:1= eicosapentaenoic acid; 22:0=behenic acid.

Geographical variation in the content of stearic acid (18:0) and arachidic acid (20:0) can be clearly observed in *S. italica*. Based on this, it was suggested that Eastern Asian landraces had been differentiated from Central Asian landraces (Taira 1989).

The landraces of *P. miliaceum* were categorized into 4 types — AB, AE, ABE and O — based on the presence or absence of arachdic, behenic and eicosapentaenoic acids, as shown in Table 3. The European and Afghanistan landraces were of the AB type, while the Indian landraces were of the AE type. The AB, AE and ABE types were observed in the Chinese landraces; all 4 types were observed in the Japanese landraces. The weed form from Romania was of the AE type. Therefore, if an ancestral form may have been the weedy AE type, the AB type had been bred both in Europe and Asia, the ABE and O types had been bred only in Eastern Asia. This fact supports the view that *P. miliaceum* had originated around Central Asia and then spread to both Europe and Asia (Sakamoto 1987; Kimata and Negishi 2002).

Table 3. Four types categorized by the composition of minor fatty acids

Geographical region	AB	AE	ABE	O	Total
Europe to Afghanistan	10	1(weed)			11
Indian Subcontinent		4			5
China and Korea	3	2	1		6
Japan	2	4	7	13	26
Total	15	11	8	13	47

AB, containing arachidic acid and behenic acid; AE, arachidic acid and eicosapentaenoic acid; ABE, three fatty acids; and O, nothing.

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