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Classification of landraces and improved cultivars of hexaploid wheats (*Triticum aestivum, T. compactum* and *T. spelta*) grown in the USA and described in 1922

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Summary

In 1922 Clark, Martin and Ball published descriptions of 207 hexaploid wheat landraces and improved cultivars, collected in the USA: 189 bread wheat accessions (*Triticum aestivum*), 24 club wheats (*T. compactum*) and four spelt wheats (*T. spelta*). After omitting 24 bread wheat accessions with identical descriptions as other accessions, the descriptions were used here to classify the remaining 183 accessions into five clusters on the basis of 10 selected characters. Clusters 1 and 3 include mainly accessions introduced from North and West Europe. These accessions must derive from the European Zeeuwse and Gelderse landrace groups. Hence most of the accessions belonging to these two clusters belong to the North and West European heritage. Cluster 2 includes most of the accessions introduced from Australia and Canada, or belonging to the club wheats. Most accessions from the USSR[1] are included in cluster 4. Here we also find Turkey and related landraces. All but one pubescent accessions are included in cluster 5.

The wide variation of US wheats, described in 1922, forms the basis of the Foundation Germplasm wheats as defined by Cox (1991). Apparently no hard white winter wheat landraces and cultivars were described.

Abbreviations: SWS – soft white spring; SWW – soft white winter; SRS – soft red spring; SRW – soft red winter; HWS – hard white spring; HRS – hard red spring; HRW – hard red winter

Introduction

In 1922 Clark, Martin & Ball described 207 hexaploid wheat cultivars which were grown at that time and earlier in the USA. They mentioned that many were locally, whereas others were widely, adapted.

The wheat crops (bread wheat (*Triticum aestivum*), spelt wheat (*T. spelta*), club wheat (*T. compactum*) and durum wheat (*T. durum*)) are not native to the Americas. They were introduced probably by the first immigrants and it has been reported that the first wheat crop (50 grains were

[1] The draft of this paper was prepared before the discontinuation of the USSR.

sown) was grown in the eastern part of South America in 1537 (Lehmann-Nitsche, 1937).

In the area now occupied by the United States wheat cultivation started along the Atlantic coast early in the 17th century and moved westward with migrating farmers. In the Jamestown Colony maybe the first wheat was sown soon after 1621. Wheat from the Netherlands and Sweden came with settlers to New York (earlier Nieuw Amsterdam), New Jersey and Delaware from 1622 to 1638. Wheat sown in New England in 1628 and in Maryland in 1634 probably originated from Great Britain. Spanish wheats were grown in California as early as 1770, according to Clark (1936). They came with the Spanish immigrants through the West Indies and Mexico. A landrace adapted to the Sonora region of Mexico was named after this region. Later, wheats from other areas such as Australia, Chile and the USSR entered the country. An introduction of major importance was that of the wheats imported by Mennonite immigrants coming from the South USSR. These wheats later became mainly known as Turkey. All these wheats and new introductions formed the Foundation Germplasm of the present-day wheat crop of the USA (see below, Cox, 1991).

Earlier classifications of US wheats. Clark et al. (1922) summarized 29 papers on the classifications of cultivars made previous to 1922. Their treatment of these publications is limited to a few lines per publication. The first classification was published in 1844 and concerned about 30 cultivars, grown in Monroe County, New York State.

In the summer 1914 Ball thought to prepare a classification of the 'wheats of the world'. This work did not appear probably due to the fact that the description of the US cultivars already fully filled the time available. Maybe he also was informed about the work by Percival (1921), who also prepared a book containing descriptions of wheat cultivars from many parts of the world. Unfortunately, the title of Percival's book is too restricted as it does not refer to the many cultivar descriptions and their classification.

Salmon et al. (1953) divided the wheat area of the 'pre-research era' (before 1900) with their characteristic wheat cultivars in 5 regions:

– *Kansas.* The soft winter wheat and spring wheat cultivars suffered greatly from winterkilling and other hazards. Only after the immigration of Mennonites after 1874 with their wheat landraces, among them the HRW Turkey and related landraces from the Crim and adjacent areas in USSR, wheat growing became profitable (Quisenberry & Reitz, 1974). The wheat landraces they introduced belonged to the so-called Mediterranean and Krymka/Crimean landrace groups (Zeven, unpubl.). The Kansas environment would have selected types with sufficient tolerance to Kansas adverse conditions.

– *Nebraska.* After the introduction of HRW Turkey and the replacement of soft winterkilled winter wheat and spring wheat cultivars wheat growing became profitable.

– *Northern Great Plains.* HRS Red Fife and semi-hard red winter Bluestem made wheat growing profitable. Later the HRS Power, selected from HRS Red Fife, and HRS Haynes Bluestem, selected from winter wheat Bluestem were grown (see below). Around 1895 HRS Preston from Canada was introduced.

– *Pacific Northwest.* Cold winter damaged the SWS cultivars. These were mostly the SWS Little Club, a compactum wheat introduced from Chile, the soft to semi-hard white spring Pacific Bluestem, derived from Bluestem material, originally introduced from Australia, and SWS Red Chaff and SWS Jenkins, both being compactum wheats with unknown history. The SRW Red Russian, selected from the British Squarehead, the SWW Goldcoin, probably selected from Redchaff Bald, which was already grown near New York in 1798, and the soft to semi-hard red spring Jones Fife, a hybrid with Fultz, Mediterranean and Russian Velvet as possible parents, were also grown.

– *California.* Here the SWS cultivars Little Club (see above), Bluestem (see above), Sonora, from Mexico, and Propo, maybe also derived from Chilean wheat, were grown.

– *Eastern States.* The first cultivars came from North and West Europe with the early settlers.

Among them may have been the parental material of the SRW Red May, possibly derived from Yellow or Red Lammas, the SWW Goldcoin (see above), the SRS Purplestraw and the SRW Mediterranean. Salmon et al. (1953) described that Mediterranean came from North/West Europe. Cox (1991, see below) suggested that it came from Italy. This latter cannot be true as Mediterranean carries the *Ne2*-allele, whereas Italy is outside the area where *Ne2*-carrying wheats were grown (Zeven, 1980). Mediterranean came either 'by way of' the Mediterranean Sea from the *Ne2*-area of South USSR, or, as suggested by Salmon et al. (1953) from North/West Europe. This region was originally a non-carrier area, but after the import of consumption (*Ne2*) wheat grains from Eastern Europe since the 14th century (Zeven, 1980, 1986) and the use of this imported material as sowing seed, it also became an *Ne2*-area.

Cox et al. (1985) identified major and minor ancestors of 43 US HRW wheat cultivars. The major ancestors are the HRW Turkey, the SRW cultivars Kawvale and Mediterranean, the HRS cultivars Red Fife, Hard Red Calcutta and Kenya 58, and the SRS Purplestraw. Except for Kawvale, Hard Red Calcutta and Kenya 58 all these cultivars are included in our research.

Murphy et al. (1986) clustered 110 winter cultivars using the coefficients of parentage. They found that 87 of the cultivars were grouped into 13 clusters, which were mainly separated on grain hardness and by geographical origin of predominant parents within classes. The remaining 23 cultivars were scattered about. Two older accessions, SRW Mediterranean, and HRW Turkey, were included in the analysis. Both cultivars were observed to be the most important ancestors in the SRW and HRW classes respectively. The authors described Turkey as the cornerstone of the HRW germplasm. However, the way these ancestral cultivars are identified by Murphy et al. (1986) is subject to doubts. First, for instance Turkey has been reported to be used as parent in the pedigree of several cultivars. For each separate cross another genotype of this landrace/landrace group will have been used. When these genotypes would have carried different names Turkey would probably not have been identified as a major parent, belonging to the Foundation Germplasm. Similarly, crossing parents with different names, but belonging to the same landrace (group) would not be recognized as Foundation Germplasm. Secondly, the assumption that each parent contributes equal numbers of genes to its derived cultivar is not correct. The assumption would mean that no selection is expected to occur. Of course, we know that the studied cultivars are the result of both natural and human selection. However, Cox et al. (1985) found a low but significant correlation coefficient between genetic relationship based on coefficient of parentage and genetic relationship based on gliadin PAGE patterns.

US Foundation Germplasm. Cox (1991) developed the concept of Foundation Germplasm of the present-day US bread wheat cultivars. This germplasm is defined as the wheat cultivars introduced into what is now the USA from the 17th to early 20th century. He observed four bread wheat classes (for the numbers and a short description of the cultivars see Table 1):

1. Soft red winter: with main parents Mediterranean (158), Purplestraw (48), Flint (43), Michigan Amber (according to Clark et al. (1922) synonymous to Red May (86)), Valley (described by Clark et al. (1922) as Gipsy (115)), Rice (28), Harvest Queen (38) and Poole (83). It is already remarked here that Clark et al. (1922) described Purplestraw as an SRS wheat. Cox (1991) stated that the cultivars Mediterranean (158), Purplestraw (48) and Flint (43) derived from landraces introduced by early colonists from North and West Europe.

2. Hard Red Winter: various Turkey (128) introductions and closely related introductions like Kharkof, Crimean and Beloglina (see Kanred, 129). They were introduced from South-West USSR.

3. Hard Red Spring: Red Fife (53), a landrace, originally from Poland, but probably adapted to Canadian conditions, and especially its derivative Marquis (52), both from Canada. Further, Kota (131) also from USSR.

Table 1. Cultivars included in the study: code number, name, synonym and origin, year of first record, first three principal component scores and cluster number

Nr.	Name (synonym); origin	Year	PC1	PC2	PC3	C
Triticum aestivum						
1	Winter Bluestem; Turkey/Pacific Bluestem	1912	−0.12	1.17	0.25	1
2	Martin (Martin Amber); single plant selection in Clawson	1875	1.45	0.93	1.40	1
3	Prohibition; new name for a cultivar of which the name was forgotten	1885	0.77	1.65	0.72	1
4	Greeson; unknown origin	1919	0.08	0.99	0.05	1
5	White Winter; probably of English origin	1855	0.10	2.38	0.04	1
+	Challenge (Webb's Challenge White); English selection from White Victoria	1885				
6	Eaton; old English origin, similar to White Winter and Challenge	1894	0.10	2.38	0.04	1
7	White Wonder; unknown origin	1919	0.16	0.59	−0.03	1
8	Satisfaction (Smith's Rust Proof); unknown origin	1904	0.16	0.59	−0.03	1
9	Early Defiance; selection from Defiance	1920	−2.09	−0.35	0.46	2
10	Colorado no. 50; selection from Defiance	1909	−2.09	−0.35	0.46	2
11	Touse; maybe related to the French landrace Touzelle from Marseille	1870	−0.63	−0.45	0.86	2
12	Defiance; Golden Drop/White Hamburg	1878	0.12	0.12	1.79	2
13	Rink; unknown origin	1909	−0.83	1.23	1.12	2
14	Bunyip; Rymer/Maffra, introduced from Australia	1901	−2.15	1.52	0.36	2
15	Pacific Bluestem; introduced from Australia maybe White Lammas (has no blue stem)	1850	−0.64	2.03	1.54	2
16	Mexican Bluestem; introduced from Mexico		−0.40	2.21	1.34	2
17	Dart (Dart's Imperial); selection from a purple-strawed cultivar, Australia	1915	−1.47	0.71	1.21	2
18	Gypsum (Blount's Lambrigg); unknown origin	1900	−1.12	0.88	1.38	2
19	Surprise (Pringle's Surprise); Chile Club/Michigan Club, if the parents were true club wheats, Surprise should have been a club wheat too	1879	−0.83	2.15	1.10	2
+	Dicklow; selection from Surprise	1912				
20	Bobs; Blount's Lambrigg/probably T. durum hordeiforme, introduced from Australia		−2.37	−0.25	1.55	2
21	Quality; unknown origin	1918	−2.78	−0.34	1.12	2
22	White Fife; probably selection from Red Fife	1889	−2.34	−0.89	0.87	2
23	White Federation; white eared selection from Federation, introduced from Australia	1910	−2.65	−0.11	1.00	2
24	Lynn (Lynn Rust Proof); selection from Defiance or Surprise	1912	−1.05	0.46	2.11	2
25	Regenerated Defiance; selection from Defiance	1907	−0.64	0.46	2.71	2
26	New Zealand; unknown origin	1890	−0.51	1.25	1.61	2
27	Pilcraw (Pilcraw Enormous); unknown origin	1917	−1.45	1.86	0.69	2
28	Rice; unknown origin	1883	−0.63	0.30	−1.43	1
29	Minhardi; Odessa/Turkey	1902	0.54	0.82	−0.51	1
30	Lofthouse; unknown origin	1890	0.69	0.01	−0.67	1
31	Big Frame; unknown origin	1895	0.69	0.01	−0.67	1
32	Buffum no. 17; awned selection from Turkey	1912	1.78	0.09	−0.19	1
33	Leap (Leap's Prolific); selection from Mediterranean	1901	0.38	−0.60	−0.86	1
34	Ontario Wonder; unknown origin Canada (?)	1888	1.10	0.09	−0.25	1
35	Zimmerman; unknown origin	1837	−0.16	0.47	−0.85	1
36	Walker; unknown origin, before 1871	1871	0.60	0.73	−0.25	1
37	Harvest Queen; unknown origin	1895	0.74	1.62	−0.09	1
38	Prosperity (American Bronze); Martin Amber/Fultz	1890	0.54	0.82	−0.51	1
+	Forward; selection from Fulcaster	1920				
39	Squarehead; introduced from Great Britain	1908	2.06	1.33	0.67	1
40	Red Russian; selection from Squarehead	1919	0.63	1.80	−0.60	1
+	Sol; South Sweden landrace/English Stand-Up, introduced from Sweden					
41	Oakley (Extra Early Oakley); unknown origin	1891	−0.02	−0.34	−1.01	1
42	Wyandotte (Wyandotte Red); unknown origin	1886	0.75	−0.08	−0.42	1
43	Flint; unknown origin	1887	−0.28	0.47	−1.26	1
44	Fultz; awnless selection from Lancaster	1862	0.69	0.01	−0.67	1
+	Ashland; selection from Fultz	1919				
45	Trumbull; selection from Fultz	1908	1.43	0.58	0.26	1
46	Fultzo-Mediterranean; unknown origin	1899	−0.08	1.46	−0.94	1
47	Kinney; probably introduced from France	1870	0.32	0.93	0.88	1
48	Purplestraw; unknown origin	1822	−0.94	−0.57	0.05	2
49	Huston; selection from Bulgarian Red Spring	1876	−1.77	−0.21	−0.18	2
50	Alton (Ghirka Winter); introduced from the USSR	1900	0.55	−0.78	0.42	1
51	Red Bobs; selection from Bobs, introduced from Canada	1910	−1.84	−0.84	0.91	2
52	Marquis; Hard Red Calcutta/Red Fife, introduced from Canada	1892	−2.87	−0.28	0.06	2
53	Red Fife; introduced from Poland via Scotland and Canada, similar material occurred in Galicia, Poland and West USSR	1860	−1.84	0.09	0.88	2
+	Power, selection from Red Fife	1885				
+	Rysting; selection from Red Fife	1892				
54	Glyndon; selection from Red Fife	1891	−0.77	−1.68	1.36	4
55	Wellman (Wellman's Fife); selection from Red Fife	1884	−0.04	−1.43	1.19	4
56	Early Red Fife; selection from Red Fife, introduced from Canada	1908	−1.49	−0.66	1.08	2
57	Ghirka (Ghirka Spring); introduced from the USSR	1898	−1.98	−0.50	0.01	2
58	Ruby; Downy Riga/Red Fife introduced from Canada	1917	−3.28	−0.36	−0.37	2
59	Kitchener; selection from Marquis, introduced from Canada	1911	−1.43	−0.75	1.33	2
60	Climax (Jones Climax); found in cv. Long Berry Dawson	1898	2.47	−0.29	0.77	3
61	Kofod; unknown origin	1870	−0.00	−0.22	0.20	1
62	Dawson; selection from Seneca or Clawson	1881	0.48	0.83	−0.30	1
+	Honor; selection from Dawson's Golden Chaff	1915				
63	Schonacher; unknown origin	1917	0.20	−0.55	−0.08	3
64	Arcadian (Early Arcadian); Early Genesee Giant/Early Red Clawson	1895	−1.10	2.11	−1.41	1
65	Windsor (Extra Early Windsor); unknown origin	1892	−0.28	0.57	−0.89	1
66	Goldcoin (Gold Coin); maybe selection from Redchaff or Redchaff Bald	1798	−0.43	1.38	−0.73	1
67	John Brown; Hornblende/3/Improved Fife//Blé Carré/Wards White/4/ Lambrigg Australian Talavera, introduced from Australia	1891	−0.48	1.23	1.43	2
68	Allen (Red Allen); unknown origin	1900	1.27	−0.10	2.75	3
69	Federation; Improved White/Yandilla, introduced from Australia	1900	−2.73	1.53	−0.69	2
70	Foisy; unknown origin	1865	1.52	−0.02	1.99	3
71	Hard Federation; selection from Federation, Australia	1907	−3.57	0.40	0.07	2
72	Gold Drop; old English cultivar	1834	−0.44	−0.67	−2.20	1
73	Homer; unknown origin	1919	1.42	0.33	−0.52	3
74	Red Wave; Early Red Clawson/unnamed Russian hybrid	1906	1.42	0.33	−0.52	3

Table 1. Continued

Nr.	Name (synonym); origin	Year	PC1	PC2	PC3	C
+	Fleming; introduced from the USSR					
75	Peterson (Lars Peterson); unknown origin	1895	1.82	0.41	−0.09	3
76	Odessa; introduced from the USSR	1893	2.43	0.35	0.03	3
77	Ruddy; Jones Fife/Little Club//Jones Fife/Turkey	1910	2.38	1.56	0.40	3
78	Rupert (Rupert's Giant); unknown origin	1900	1.01	0.24	−0.94	3
79	Rural New Yorker no. 6; Martin/rye	1883	−1.13	0.37	−2.55	1
80	Squareheads Master 1091; maybe Scholey's Squarehead/Goldendrop, introduced from England	1911	0.95	2.04	−0.87	1
81	Currell (Currell's Prolific); selection from Fultz	1881	−0.51	−0.27	−2.12	1
82	Winter Chief; unknown origin	1913	0.05	0.89	−1.63	1
83	Poole; unknown origin	1884	1.17	0.73	−0.57	3
+	Portage 1121; unknown origin	1916				
+	Russian Red; unknown origin	1888				
84	China; introduced from China	1845	2.91	0.03	0.37	3
85	Wheedling; unknown origin	1890	1.97	1.48	−0.02	3
86	Red May; probably identical to the English Red Lammas	1764	0.71	−0.02	−0.85	3
87	Illini Chief; unknown origin	1915	2.03	1.39	0.24	3
88	Red Clawson (Early Red Clawson); Clawson/Golden Cross	1888	0.86	1.05	−0.78	1
89	Rochester (Rochester Red); unknown origin	1891	0.24	1.69	−1.20	1
90	Red Chief (Early Red Chief); similar to Rochester	1903	0.86	1.05	−0.78	1
91	Schlanstedt (Rimpau's Red Schlanstedter Sommerweizen); selection from Bordeaux, introduced from Germany	1889	1.60	0.52	1.30	3
92	Resaca (Red Resaca); unknown origin	1919	0.15	−0.39	0.04	3
93	Stanley; Ladoga/Red Fife, introduced from Canada	1895	1.10	−0.33	2.29	3
94	Silvercoin; probably Goldcoin/Sonora	1900	−1.42	2.05	−2.16	5
95	Jumbuck; Improved Fife/Tardent's Blue//Lambrigg Australian Talavera, Australia	1910	−0.52	0.77	2.42	2
96	Indian; probably Sonora/?	1875	−3.24	0.18	−2.10	5
97	Triplet; similar to Ruddy	1910	−0.13	−0.47	−1.73	5
98	Mealy; selection from Fultz	1885	0.20	0.02	−1.23	5
99	Jones Fife (Jones Winter Fife); Fultz/?/Mediterranean/?/Russian Velvet	1889	0.08	−0.18	−1.92	5
100	Haynes Bluestem; selection from Bluestem	1882	−0.13	−0.75	0.76	5
+	Dakota; selection from Haynes Bluestem	1898				
101	Galgalos; introduced from Erivan, USSR	1903	−0.09	−0.76	−0.42	5
102	Sonora; introduced from Mexico	1800	−2.73	1.71	−1.71	5
103	Grandprize (St. Louis Grand Prize); unknown origin	1905	−0.83	1.51	−3.13	5
104	Democrat; unknown origin	1883	1.17	0.60	0.72	1
105	Seneca Chief; unknown origin	1900	0.58	0.60	−0.38	1
106	Oatka Chief; unknown origin	1897	1.06	0.77	0.21	1
107	Mammoth Amber (Jones Mammoth Amber); American Bronze/Early Genesee Giant	1906	0.75	1.09	−0.00	1
108	Palisade (White Palisade); unknown origin	1907	−0.28	−1.42	0.61	4
109	Propo; unknown origin	1879	−0.78	−0.79	0.61	4
110	Treadwell; unknown origin	1868	1.32	−0.21	0.56	1
111	Baart (Early Baart); introduced from South Africa via Australia	1914	−0.93	−1.16	1.05	4
112	Talimka; introduced from Turkestan, USSR	1904	−2.33	−3.39	0.40	4
113	Nebraska no. 28; Big Frame/Turkey	1902	−0.49	−1.48	−2.11	4
114	Gladden; selection from Gipsy	1905	0.82	−1.25	−0.73	4
115	Gipsy; unknown origin	1877	0.82	−1.25	−0.73	4
116	Valley; unknown origin	1884	1.64	−1.08	0.11	3
+	Wisconsin Pedigree no. 40; unknown origin	1917				
117	Sibley (Sibley's New Golden); Mediterranean/Clawson	1919	1.12	−1.68	−1.34	4
118	Fulcaster; Fultz/Lancaster	1886	0.89	−0.16	−0.76	1
+	Mammoth Red; unknown origin	1904				
119	Diamond Grit; Jones Winter Fife/Early Genesee Giant	1896	0.41	−1.33	−1.16	4
120	Golden Cross; probably Mediterranean/Clawson, similar to Diamond Grit	1888	0.00	−1.41	−1.58	4
121	Champlain (Pringle's Champlain); probably Black Sea/Goldendrop	1877	0.36	−0.79	1.52	4
122	Java (Early Java); unknown origin	1837	−0.45	−2.35	−0.36	4
123	Erivan; introduced from Erivan, USSR	1903	−1.27	−2.52	−1.21	4
124	Converse; unknown origin	1908	0.71	−1.31	1.17	4
125	Minturki; Odessa/Turkey	1902	0.84	−2.28	−0.77	4
126	Hussar (Red Hussar); unknown origin	1906	1.69	−1.91	−0.08	4
+	Pesterboden; unknown origin	1919				
127	Blackhull (Clark's Black Hulled); selection from Turkey	1912	0.46	−1.90	−0.10	4
128	Turkey (Turkey Red); landrace, introduced from the USSR	1873	0.34	−2.91	−0.32	4
+	Iowa no. 404; selection from Turkey	1913				
+	Iowa no. 1946; selection from Turkey	1920				
+	Montana no. 36; selection from Kharkof	1915				
+	Nebraska no. 60; selection from Turkey	1918				
+	Wisconsin Pedigree no. 2; selection from Turkey	1918				
129	Kanred; selection from Crimean	1905	0.34	−2.91	−0.32	4
+	Beloglina; introduced from the USSR	1900				
+	Bacska; introduced from Hungary	1900				
130	Preston (Velvet Chaff); Ladoga/Red Fife, introduced from Canada	1888	−0.73	−2.33	0.90	4
131	Kota; introduced from the USSR	1903	−0.66	−2.73	0.82	4
132	Pioneer; Riga/Preston, introduced from Canada	1903	−1.36	−3.08	0.48	4
133	Rudy; unknown origin	1871	2.56	−1.69	−0.06	3
134	Gluten (Gluten B86); unknown origin	1902	1.37	−0.48	−0.42	1
135	Nigger; unknown origin	1884	1.37	−0.48	−0.42	1
136	Silversheaf (Jones Silver Sheaf Longberry Red); American Bronze//Lancaster/Seedling no. 91 Longberry	1903	2.47	−1.44	0.35	3
137	Fretes; introduced from Algeria	1901	0.18	−1.60	0.05	4
138	Dixon (Humpback II); unknown origin	1916	1.82	−1.89	2.12	4
139	Chul; introduced from Turkestan, USSR	1902	−1.22	−3.40	0.56	4
140	Link (Missing Link); unknown origin	1912	2.19	1.18	0.79	3
141	Emerald (Early Spring); unknown origin	1913	−0.25	−1.53	0.60	4
142	Genesee Giant (Early/Genesee Giant); Golden Cross Jr/Hybrid//Iron Straw	1893	−0.16	1.02	−0.63	1
143	Canadian Red; unknown origin	1919	−2.11	−2.55	−0.27	4
144	Longberry No. 1 (Jones Longberry no. 1); Mediterranean/Russian Velvet	1898	1.78	−0.78	0.13	3
145	New Amber Longberry; unknown origin	1899	2.46	0.37	1.05	3

Table 1. Continued

Nr.	Name (synonym); origin	Year	PC1	PC2	PC3	C
146	Sevier; unknown origin	1918	−2.39	−1.42	−0.19	4
147	Diehl-Mediterranean; Red Mediterranean/Diehl	1884	1.14	−0.00	−1.19	3
148	Russian; unknown origin	1917	0.87	0.50	−0.74	3
149	Imperial Amber; unknown origin	1913	1.35	−0.73	−1.19	3
150	Goens; unknown origin	1808	0.91	−0.18	−0.94	3
151	Cox; unknown origin	1900	1.43	0.26	−1.28	3
152	Yaroslav; introduced from the USSR	1899	1.83	−1.15	0.14	3
153	Huron; White Fife/Ladoga, introduced from Canada	1888	−0.20	−1.81	0.44	4
154	Norka; bread wheat selection from Kubanka durum wheat	1908	−0.34	−2.50	0.55	4
155	Ladoga; introduced from the USSR via Canada	1888	−0.77	−2.27	0.46	4
156	Laramie; selection from Spring Turkey	1914	−0.62	−3.07	0.30	4
157	Ariette; probably originally introduced from Italy	1919	1.55	−1.93	−0.39	3
158	Mediterranean; introduced via the Mediterranean Sea	1837	2.17	−0.56	−0.34	3
159	Red Rock; similar to Mediterranean	1908	1.75	−1.13	0.04	3
160	Bearded Winter Fife; Jones Fife/?	1894	−0.05	0.52	−1.57	5
161	Read (Read's Vermont Winter); Bearded Fife/probably Early Arcadian	1898	−1.49	1.00	−2.84	5
162	Rural New Yorker no. 57; unknown origin	1894	0.68	−0.26	−1.59	5
+	Pride of Genesee; unknown origin	1893				
+	Virginia; CI 1344/Jones Fife	1905				
163	Prelude; Fraser/Downy Gehun, Canada	1903	−3.42	−1.30	−1.99	5
164	Humpback; unknown origin, maybe sister of Dixon	1905	1.11	−1.48	0.47	5
165	Penquite (Penquite's Velvet Chaff); unknown origin	1857	0.95	−0.63	−2.63	5
Triticum compactum						
166	Hybrid 128; Jones Fife Winter/Little Club	1899	−0.61	2.04	−0.30	1
167	Little Club; maybe introduced from Chile	1865	−1.12	1.89	1.19	2
168	Big Club; maybe introduced from Chile	1866	−1.12	1.89	1.19	2
169	Hybrid 143; White Track/Little Club	1899	−1.18	1.98	0.93	2
170	Hybrid 60; Turkey/Little Club	1905	−2.37	0.67	1.52	2
171	Hybrid 63; Turkey/Little Club	1899	−2.16	0.96	1.33	2
172	Hybrid 108; Jones Fife/Little Club	1899	−1.00	1.22	0.12	2
173	Hybrid 123; Jones Fife/ Little Club	1899	−0.86	1.11	0.48	2
174	Jenkin (Jenkin's Club); unknown origin	1900	0.31	2.55	1.68	2
175	Redchaff (Red Chaff Club); unknown origin	1907	−1.21	2.04	0.49	2
176	Bluechaff (Blue Chaff Calvert Club); unknown origin	1897	−0.51	2.39	0.83	2
177	Dale (Dale Gloria); unknown origin	1900	−1.09	1.38	−0.57	2
178	Coppei; probably Little Club/Jones Fife	1907	−0.69	1.27	−2.19	5
*	Wilbur (Early Wilbur); selection from Jenkin's Club	1899				
179	Mayview; selection from Fortyfold	1911	0.36	0.83	−0.06	3
Triticum spelta						
180	White Spring; unknown origin	1904	0.52	−0.28	1.69	2
181	Alstroum; unknown origin	1901	1.45	−0.05	0.63	1
182	Red Winter; unknown origin	1901	2.18	0.76	−0.02	3
183	Bearded; unknown origin	1901	1.84	0.25	0.50	3

+ The cultivars were not included in the analysis because their data were (nearly) identical to the preceeding numbered cultivar; principal component scores and cluster number will be identical too.

* The cultivar was not included in the analysis because there was too little descriptive information.

N.B. For easy reference the sequence of cultivar description in Clark et al. (1922) has been followed.

4. White: the 19 cultivars can be divided into provenances:

4a. Cultivars from Australia: soft and semi-hard WS Baart (111, originally from South-Africa), SWS Federation (69), WSW Pacific Bluestem (15), Onas (not included by Clark et al., 1922), SWS Bunyip (14).

4b. Cultivar from Mexico: SWS Sonora (102).

4c. Cultivar from unknown area: SWW Goldcoin (syn. Fortyfold (66)). This cultivar may also derive from North/West European material.

4d. Cultivars from Chile: the compactum wheats SWS Big Club (168) and SWS Little Club (167).

Each landrace and old cultivar probably existed as many genotypes, while the same may be true for some of the improved cultivars. The multiple introduction of wheat landraces from Southwest USSR between 1874 and 1900, all named Turkey, must have resulted in the introduction of many, related, genotypes. Hence, the many synonyms (Clark et al., 1922). So, Quisenberry & Reitz (1974) considered Turkey 'as a type rather than a specific variety ...'. We would have called this 'type' a landrace group with the US name Turkey, and maybe a Russian name Krymka. According to Percival (1921) Turkey Red (128), Malakov, Banat, Lancaster and material from European USSR, Austria, Hungary, Rumania, the USA and Canada are similar.

The fact that the spring wheat Haynes Bluestem (100, with dominant alleles inhibiting vernalization requirement) could be selected from the winter wheat Bluestem (syn. Red Winter) (with recessive alleles) points either to heterogeneity of Bluestem, or to an error in the history record of Haynes Bluestem. This is further supported by the fact that

Haynes Bluestem carries the allele *Hg* for pubescent glumes, whereas Bluestem has *hg* for glabrous glumes. However, Percival (1921) described Haynes Bluestem as a winter wheat. If Haynes Bluestem indeed derives from a Bluestem cultivar from Australia (see below), then it may be assumed that this Australian material was a spring wheat. In addition, other wheat cultivars were also named Bluestem (Clark et al., 1922). An example of variation in an old improved cultivar is Marquis, in which Harrington (1927) found over 20 morphotypes.

Usefulness of classification. Zeven (1990a, 1990b) summarized the usefulness of classifying wheat cultivars. Classification can clarify the history of a crop as was shown by Zeven & Schachl (1989), who discovered a third landrace group by clustering Austrian alpine wheat landraces. As this landrace group was identified its origin could be studied. Knowledge about genetic diversity of (a part of) a genepool is also essential for germplasm curators conserving and exploiting genetic variation (van Hintum, 1991), or breeders searching for good parental combinations. The present study gives an analysis of the diversity as described in the earlier publication of Clark et al. (1922).

Materials and methods

Materials. The data set was created on the basis of the descriptions of 207 old US wheat cultivars by Clark et al. (1922). Abridged descriptions of this material are presented in Table 1, giving the number, the cultivar name sometimes followed by a synonym, information on its origin and the year it was first mentioned. The year gives the approximate time of first (large-scale) growth or the time the cross was made or an ear was selected, indicating the period to which the cultivar belongs. 23 Cultivars, whose descriptive data were (almost) equal to cultivars already in the data set, were omitted. One cultivar, Wilbur, was excluded because there was too little descriptive information. The remaining 183 accessions were used in the analysis.

Character scores. Clark et al. (1922) described each cultivar in general terms. From these descriptions we selected 10 characters as they could have been those of interest to farmers and seed traders, and could also be considered to be reliable. These characters are growth habit (winter or spring type), earliness (early, mid or late), plant height (short, mid or tall), straw stiffness (weak, mid or strong),

Table 2. Descriptors used in the analysis: average scores per cluster, scale and F values in a variance analysis on the basis of the classification in 5 clusters

Descriptor	Cluster					Scale	F-value
	1	2	3	4	5	1–5	
Growth habit	1.1	5.0	1.7	3.7	2.5	Winter-spring	70.18**
Earliness	3.1	2.5	3.8	2.5	2.9	Early-late	7.29*
Plant height	3.1	3.1	4.1	2.8	2.7	Short-tall	9.77**
Straw stiffness	4.1	4.6	3.4	2.2	3.9	Weak-stiff	24.14**
Awnedness	1.7	1.0	2.9	4.8	2.5	Awnless-awns	39.39**
Ear density	3.4	4.0	2.6	2.8	3.6	Lax-dense	10.86**
Glume hairiness	1.0	1.0	1.0	1.0	5.0	Hairless-pubescent	AZ**
Glume colour	2.1	2.0	4.5	1.8	2.0	White-red	19.25**
Grain colour	3.5	2.2	4.2	4.2	3.5	White-red	8.39*
Grain hardness	1.2	2.6	1.5	3.2	2.1	Soft-hard	16.45**
Number of acc.	53	44	36	34	16		

* Significant ($P > 0.05$)
** Significant ($P > 0.01$)

ear type (awnless or awned), ear density (lax, mid or dense), glume hairiness (glabrous or pubescent), glume colour (white, yellow or brown), grain colour (white or red) and grain hardness (soft, mid or hard). These descriptors could all be scored on a quantitative scale (Table 2). Other characters presented by Clark et al. (1922) included stem colour, ear shape, ear attitude, glume length, glume width, shoulder shape, beak shape, apical awns, grains shape, germ shape, crease shape, cheek shape, brush size and length. These were not used in our investigations.

Statistical analysis. After standardization of the data, a hierarchical cluster analysis was performed using city block distances and the group average cluster algorithm.

As Cox (1991) concluded that the bread wheat and club wheat Foundation Germplasm cultivars could be divided into four classes and as Clark et al. (1922) included one extra group of four spelt cultivars, it was decided to classify Clark et al.'s material in five clusters by cutting the dendrogram resulting from the clustering at a 60 percent level of similarity.

On the basis of an analysis of variance it was determined to which extent this classification could explain the variance of the different descriptors.

The 10 descriptors were also used in a principal component analysis.

All computations were performed using the statistical software package GENSTAT (Anon., 1987).

Results

The coefficients of correlation between the ten descriptors used in the classification and principal component analysis are given in Table 3. In Table 2 the average score per group per descriptor is given. The F values of these descriptors in an analysis of variance on the basis of the classification in 5 clusters are also given.

A comparison of the classification in 5 clusters and the grouping on the basis of only grain hardness, grain colour and growth habit is given in Table 4. Apparently no hard white winter wheats were described by Clark et al. (1922).

The first three principal components explained 49.0% of the total variation (19.1, 17.6 and 12.4% respectively). The vector loadings of the first three principal components are shown in Table 5. Figure 1 gives the distribution of the 5 clusters in the area of the first two principal components. As the first two principal components explain 36.7% of the total variation only, this area only shows a limited part of the total variation. Figure 2 gives the distribution of the clusters on the first and third principal components. Figure 3 shows the distribution of the material from different origins in the area of the first two principal components. Figures 4, 5 and 6

Table 3. Coefficients of correlation between descriptors

Earliness	−0.24**								
Plant height	−0.08	0.41**							
Straw stiffness	−0.01	0.16*	0.07						
Awnedness	−0.10	0.02	0.03	−0.36**					
Ear density	0.12	−0.14	−0.29**	0.33**	−0.17*				
Glume hairiness	−0.04	−0.01	−0.15*	0.05	0.02	0.08			
Glume colour	−0.09	0.09	0.02	−0.03	−0.03	0.02	−0.08		
Grain colour	−0.28**	0.03	0.06	−0.15*	0.14	−0.18*	0.01	0.01	
Grain hardness	0.42**	−0.19*	−0.17*	−0.09	0.16*	−0.10	0.02	−0.13	0.11
	growth habit	earliness	plant height	straw stiff.	awnedness	ear dens.	glume hairi.	glume colour	grain colour

* Significant ($P > 0.05$)
** Significant ($P > 0.01$)

show the distribution of grain hardness, grain colour and growth habit respectively.

The 5 clusters formed in the hierarchical classification can be characterized by their location on the first three principal components (Table 1, Fig. 1 and Fig. 2). These locations can be interpreted as character combinations (Table 5), that can be verified and extended with the data in Table 2:

Cluster 1: The 53 accessions in this cluster are characterized by having medium to high scores on the first, and high scores on the second principal component. The accessions are, in general, SRW and SWW wheats with strong straw and hairless glumes.

Cluster 2: The 44 accessions in this cluster are characterized by having low scores on the first, and high scores on the second principal component. All accessions are of the spring type, have strong straw and are awnless. The ears are quite dense and the glumes hairless.

Cluster 3: The 36 accessions in this cluster are characterized by having high scores on the first, and medium scores on the second principal component. The accessions are in general tall SRW types with red, hairless glumes.

Cluster 4: The 34 accessions in this cluster are characterized by having low scores on the second principal component. The accessions of this cluster are in general awned, have hairless glumes and red grains.

Cluster 5: The 16 accessions in this cluster are characterized by having low scores on the third principal component. The accessions of this cluster all possess pubescent glumes.

Table 4. Comparison of the classification in 5 clusters and the grouping on the basis of only grain hardness, grain colour and growth habit

Group	Cluster					Total
	1	2	3	4	5	
SWW	19		4		3	26
-WW		1		1		
SRW	30		21	6	5	62
-RW	1		3	2	2	8
HRW	1		1	3		5
SW-	1					1
SWS		21	1	4	3	29
-WS		1	1			2
HWS		9		3		12
SRS	1	5	3	4		13
-RS		2		3	1	6
HRS		6	1	9	2	18
Total	53	44	36	34	16	183

Discussion

Characters association. In general, the coefficients of correlation, indicating the association between characters are quite low (Table 3), but due to the large numbers of cultivars several coefficients are significant.

The large number of SRW cultivars included in the experiment caused the association between growth habit and grain color and hardness.

Early accessions are generally short spring wheats, while late accessions tend to be tall winter wheats. The negative association between plant length and earliness can be expected in these old cultivars, since early plants have less time to grow as compared to late plants.

Dense ears can be associated with short plants, stiff straw, and to a lesser extent awnlessness, all characteristics of modern varieties.

Clusters. The five clusters resulting from the classi-

Table 5. Vector loadings of the first three principal components

Descriptor	Principal component		
	1	2	3
Growth habit	−0.459	−0.116	0.525
Earliness	0.457	0.224	0.218
Plant height	0.460	0.094	0.478
Straw stiffness	−0.098	0.547	0.109
Awnedness	0.163	−0.464	−0.121
Ear density	−0.366	0.378	−0.251
Glume hairiness	−0.114	0.027	−0.408
Glume colour	0.148	0.109	−0.124
Grain colour	0.259	−0.285	−0.313
Grain hardness	−0.309	−0.419	0.282

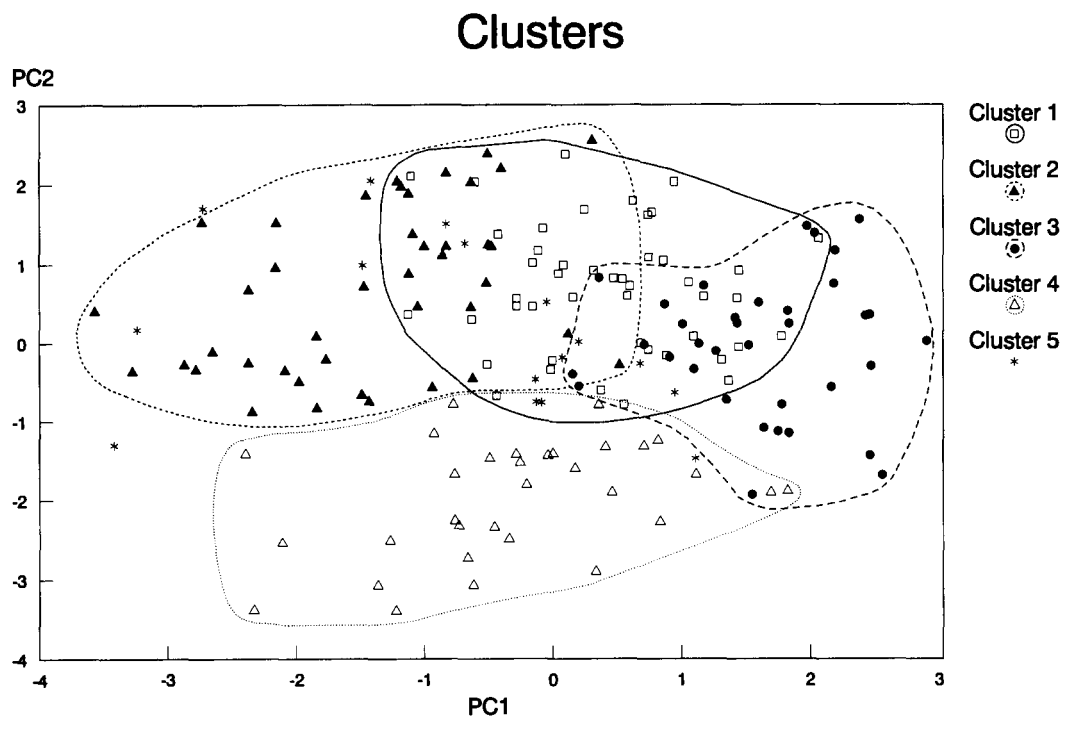

Fig. 1. Scatter diagram of the cultivars on the first two principal components, indicated are the five clusters.

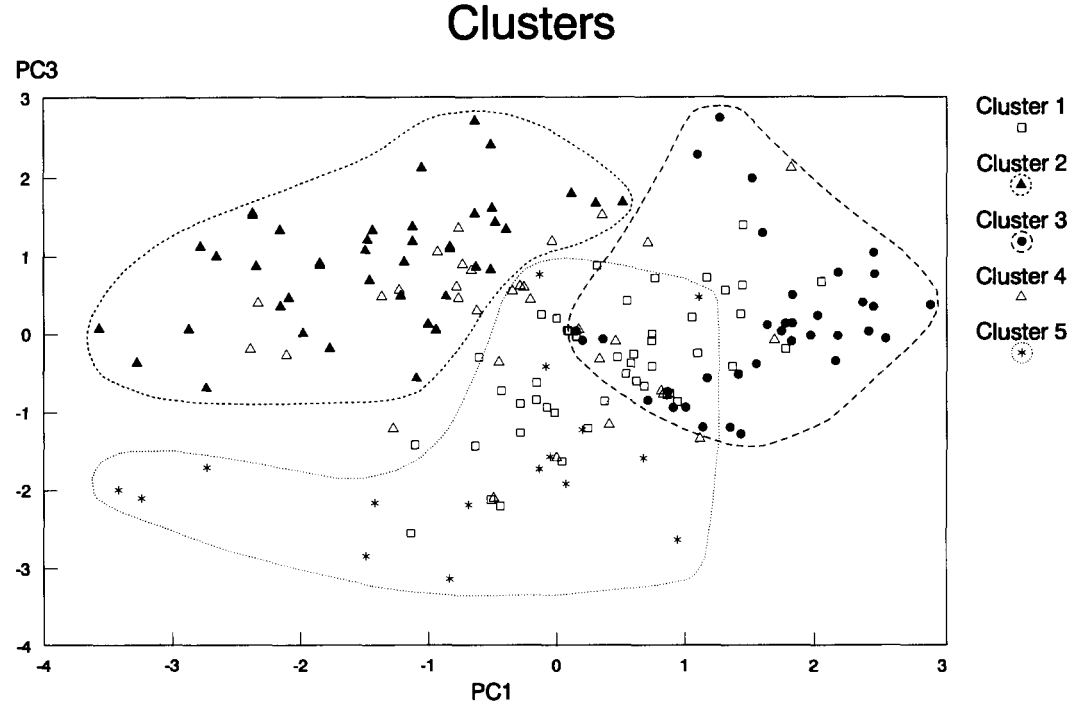

Fig. 2. Scatter diagram of the cultivars on the first and third principal components, indicated are the five clusters.

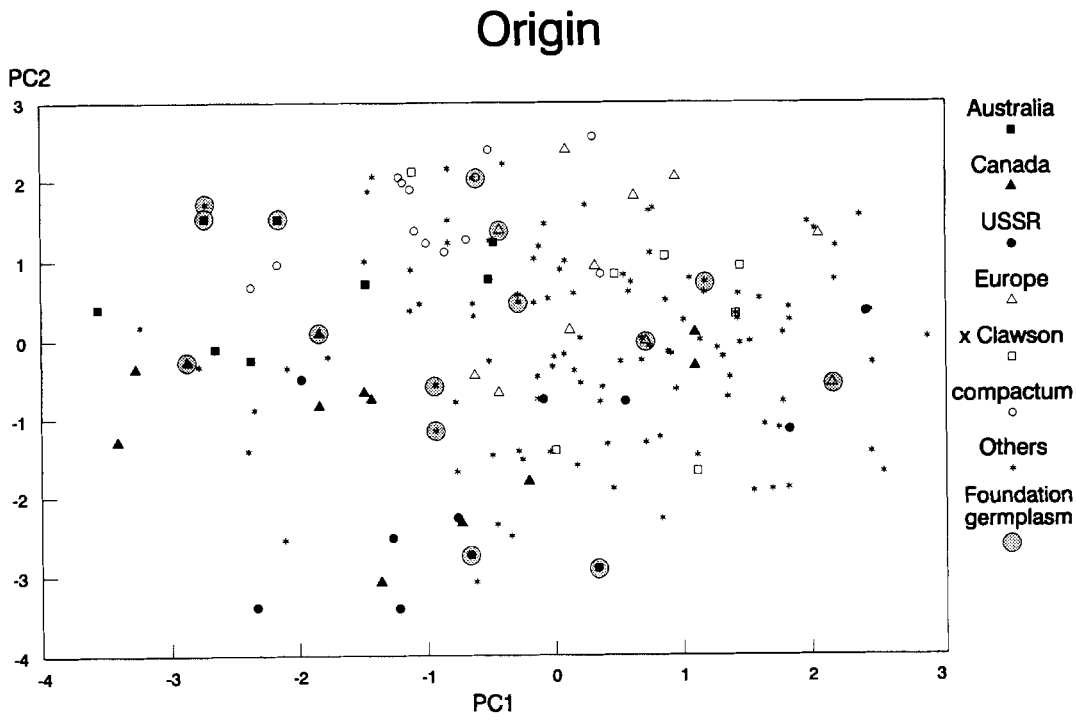

Fig. 3. Scatter diagram of the cultivars on the first two principal components, indicated are some origin groups.

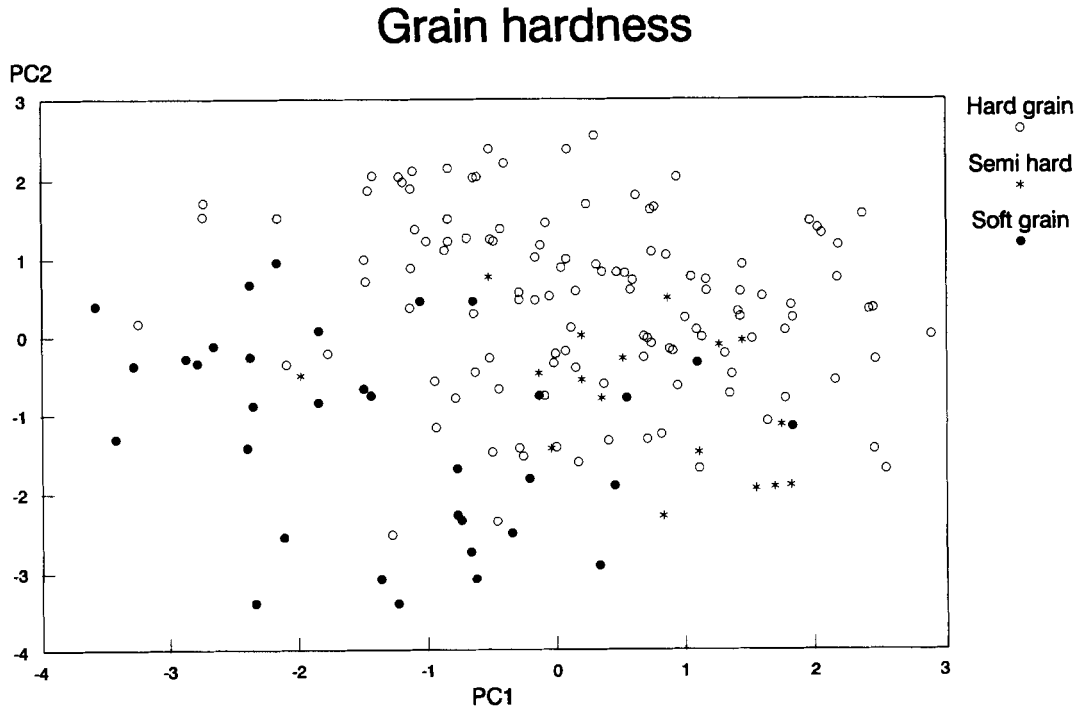

Fig. 4. Scatter diagram of the cultivars on the first two principal components, indicated is the grain hardness.

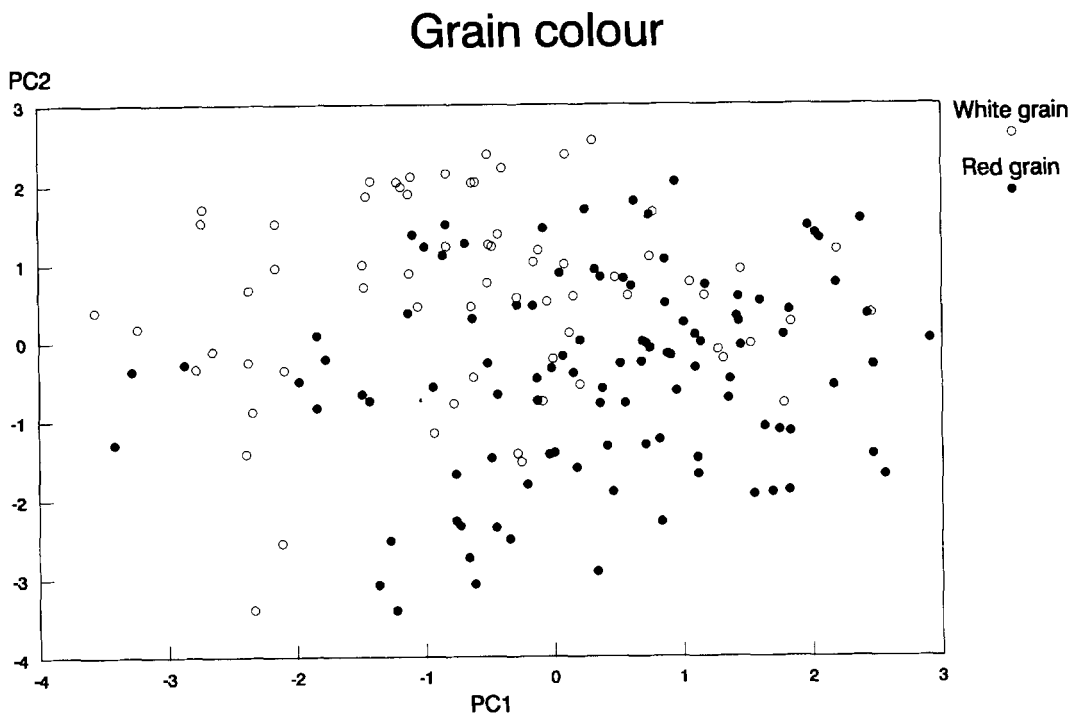

Fig. 5. Scatter diagram of the cultivars on the first two principal components, indicated is the grain colour.

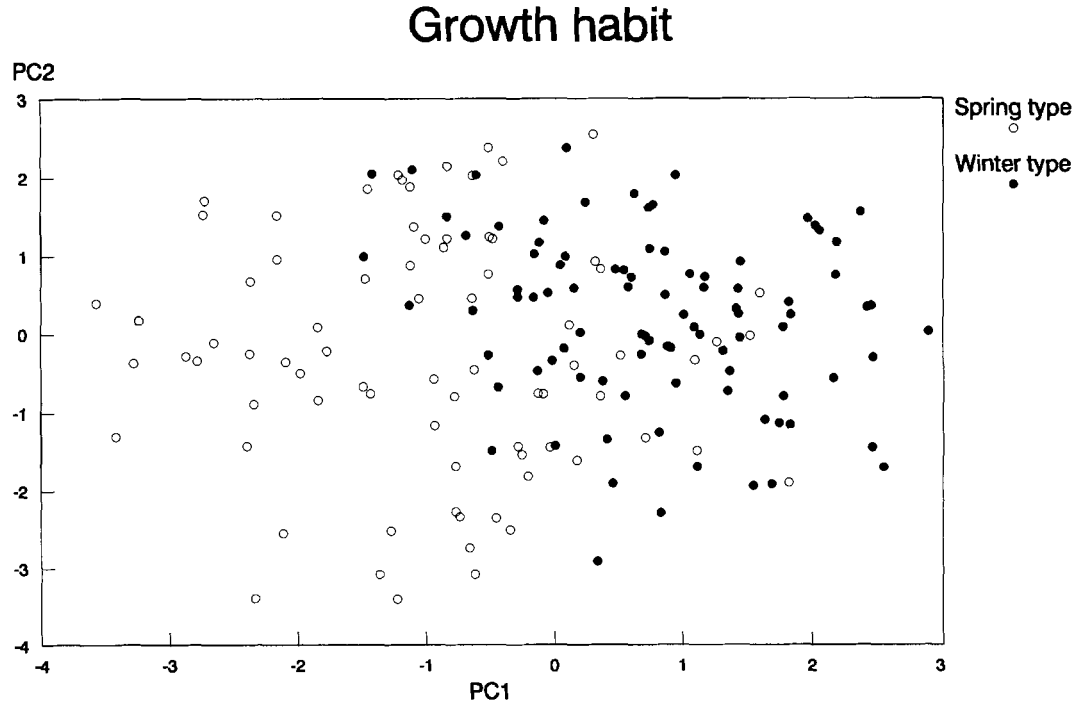

Fig. 6. Scatter diagram of the cultivars on the first two principal components, indicated is the growth habit.

fication can, to a large extent, be typified by their characteristics (Table 2). Also a parallel to other classifications and the history of the cultivars can be found:

Cluster 1: This cluster includes SWW and SRW accessions originally introduced from North and West Europe, i.e. Cox' classes 1 and 4 (subclass 4c). As North America was populated by Europeans during European global expansion it may be assumed that they took with them the wheats of their native area to grow them in their new country. Among these immigrants many came from North and West Europe and hence wheats belonging to the SWW and SRW types were introduced and grown. After the introduction of Turkey and related landraces in certain areas where the (ex) North and West European landraces did not do well they will have been replaced. But in other areas they survived and were collected and described in and before 1922.

Cluster 2. Most Australian, club wheat (see below) and Canadian cultivars occur in this cluster (Fig. 3). They include mostly SWS wheats, i.e. Cox's class 4 (subclasses 4a and 4d) and class 3 respectively.

Cluster 3. This cluster includes SRW wheats with red glumes. Zeven (1983) pointed out that if the gene for red glumes was identified it always was the *Rg* gene. Further, he concluded that this gene occurs in wheats of all wheat growing areas. Therefore, the presence of the red glume character in a group of SRW wheats is not helpful in identifying their areas of provenance. However, as, as shown in Fig. 1, this cluster overlaps that of cluster 1, it is concluded that many of the wheats of cluster 3 are red-glumed counterparts of the white-glumed SRW wheats of cluster 1. So, they may also derive from SRW wheats introduced from North and West Europe.

Cluster 4. This cluster includes most of the USSR introductions. In Fig. 3 the accessions which came from the USSR were marked. At the left side we find USSR spring wheats from Turkestan and Erivan. Here we find also Ladoga (155), which is said to come from the Petrograd area, USSR, but as it carries the *NeIm* allele (Zeven, 1969) it must originally come from the *NeIm*-area of South USSR (Zeven, 1980). At the right side USSR winter wheats from Southwest USSR. Among them are Turkey (128) and Kanred (129), both part of the Crimean/Krymka landrace group.

Cluster 5. This cluster is determined entirely by the characteristic of pubescent glumes, a character conditioned by the gene *Hg*(pubescent)/*hg*(glabrous). The 16 accessions can be subdivided:

Subcluster 5a: Sonora and Sonora derivatives: Sonora (102), Silvercoin (94, probably Goldcoin/Sonora) and Indiana (96, probably Sonora/open pollinated). Sonora probably came from the Iberian Peninsula and so did its *Hg*-allele.

Subcluster 5b: Jones Fife and Jones Fife derivatives: Jones Fife (99), Triplet (97, with parents Jones Fife, Little Club and Turkey), Bearded Winter Five (160, Jones Fife/open pollinated), Read (161, Bearded Fife/Early Arcadian) and the club wheat Coppei (178, Little Club/Jones Fife) (see below).

Subcluster 5c: others, Prelude's (163) *Hg*-allele came from Downy Gehun from India. This means that the *Hg*-allele of Jones Fife (99) and derivatives came from the Indian subcontinent. Mealy (98) is described as selected from Fultz. Fultz has, however, glabrous glumes. So, the true parent and hence the source of the *Hg*-allele is unknown. Galgalos (103) came from Erivan, USSR. Rural New Yorker no 57 (162), Humback (164) and Penquite (165) have unknown breeding histories. Jumbuck (95) is the only cultivar with pubescent glumes not included in cluster 5. Its *Hg*-allele may have come from its pubescent grandparent cultivar Tardent's Blue.

Eleven of the 14 accessions of club wheat are in cluster 2, whereas Hybrid 128 (166) is grouped in cluster 1, Mayview (179) in cluster 3 and Coppei (178) in cluster 5. Hybrid 128 derives from Jones Fife/Little Club. Jones Fife (99) is grouped in cluster 5, whereas Little Club (167) is in cluster 2. Apparently Hybrid 128 still resembles Jones Fife, in spite of its compactum ear. Mayview derives from a compactum plant found in Fortyfold, which is a synonym of Goldcoin (66). Mayview's location in cluster 3 is not supported by its possible parental variety Goldcoin, which is grouped in cluster 1. The history of Coppei is given as 'probably Little Club/

Jones Fife'. Its presence in cluster 5 could find a same explanation as given for Hybrid 128.

The North and West European heritage. Various landraces and cultivars have been described by Clark et al. (1922) to come from North and West Europe: SWW's White Winter, Eaton, Goldcoin, SWS's Touse, Defiance, SRW's Squarehead, Red Russian, Gold Drop, Squareheads Master, Red May, Mediterranean and SRS Kinney. Cox (1991) added SRW Flint and SRS Purplestraw. Not included in this list is the German Schlanstedt (91) as this cultivar is selected from the French cultivar Bordeaux. The latter is selected from the French cultivar Noe, which derives from USSR material. Percival (1921) refers to this material as Rimpau's Schlanstedt Summer Wheat, being similar to Bordeaux.

It is doubtful whether all material has an 'old English origin' (Clark et al., 1922); maybe in some cases it would have been better to refer to North and West Europe as the area of provenance.

Because most of the listed North and West European landraces and cultivars belong to clusters 1 and 3 they occur in the top right sector of Fig. 1. These landraces and cultivars are soft grain types and winter wheats. Further as the SWW White Winter, Challenge and Eaton are related to White Victoria, and White Victoria belongs to the Zeeuwse landrace group, we conclude that most of them also belong to this landrace group (Zeven, 1990), which occurred in the area of Southwest Netherlands, Flanders, Northwest France and Southeast Great-Britain. As the SRW wheats are awnless and belong to cluster 1, they could probably be included in the Gelderse landrace group (Zeven, 1990), which was derived from imported *Ne2* wheats from Eastern Europe (see above). Flint could possibly be added to this landrace group too. Purplestraw remains a problem as Clark et al. (1922) list this cultivar as a spring wheat, while Cox (1991) describes it as a winter wheat. However, it should have been listed as a spring wheat (Cox, pers. comm., 1991).

Clawson, its classification and provenance. Clark et al. (1922) described the cultivar Clawson to be a white grained wheat, identical to SWW Goldcoin (66). This cultivar is said to derive from a white grained plant found in Fultz. In pedigrees of several cultivars Clawson is mentioned as a (possible) parent. These cultivars are the SWW's Martin (2), Dawson (62) and Arcadian (64), the SRW's Red Wave (74), Red Clawson (88) and Golden Cross (120), and the SRS Sibley (117).

As already said Clawson is a white grained winter wheat, but its grain hardness is not mentioned by Clark et al. (1922). The same is true for its source cultivar Fultz. Further, as all derived cultivars are soft grained too we conclude that Clawson also is an SWW wheat. As many of the SWW wheats originally came from North and West Europe (see above) and as four of the seven derived cultivars belong to either cluster 1 or 3 it is believed that Clawson also belongs to the Zeeuwse landrace group (Zeven, 1990a).

Foundation Germplasm. Figure 3 shows that points indicating the Foundation Germplasm cultivars as identified by Cox (1991) seem equally distributed over the diagram. This supports the assumption that the Foundation Germplasm is based on a wide variation of wheat phenotypes.

Conclusions

Many bread wheat landraces, which were at an early time introduced in the USA came from North and West Europe. These landraces and derived, improved cultivars were classified into two clusters, forming the wheat heritage of this part of Europe. The landraces belonged to the group Zeeuwse and Gelderse.

Later introductions came from Southwest and South USSR, Australia, Canada and elsewhere. These wheats formed the Foundation Germplasm of the present-day US cultivars.

No effect of wheat landraces introduced from the Iberian Peninsula into California could be observed.

Most club wheats and bread wheats introduced from Australia and Canada clustered together. This was not the case for the four spelt accessions.

Apparently in 1922 no hard white winter wheats were grown in the USA.

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