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Title Study on the on-farm diversity of local date palm (*Phoenix dactylifera* L.) genetic resources grown in Northern region of Sudan

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Abstract

The status of the conservation of the date palm genetic resources (*Phoenix dactylifera L*.) in the Northern region of Sudan was assessed through morphological characterisation of mature trees on farm, by conducting interviewing farmers and by molecular analysis of samples collected from the field.

The morphological characterisation was conducted on 116 date palm female farmers' varieties and 20 male farmers' varieties in the districts River Nile and Northern States using 18 vegetative and fruit characteristics (quantitative and qualitative). The results show that there are highly significant differences among cultivars/farmers' variety with regard to all investigated characters.

The genetic diversity in the date palm farmers' varieties, 63 females and 12 males, was analyzed using microsatellite (SSR) loci. The investigated SSR markers exhibited a high level of polymorphism. A total of 92 alleles, with an average of 13.1 alleles per locus, were detected at 7 loci. A high level of expected heterozygosity was recorded among farmers' varieties from River Nile., The value for the female and soft date palm farmers' varieties were 0.804, 0.803 and 0.774, respectively.

To investigate the current status of existing on-farm date palm production regarding preferred cultivars/farmers' verities and threats facing the date palm culture, 215 date palm farmers were interviewed in River Nile and Northern State. The results show that Barakawi is the most preferred cultivar/farmers' varieties while cvs. Um-dokan, Sakot, Berira, Sagaai and Kolmah were the least. The results show that introduction of new varieties, novel diseases and some socio-economic factors were the main problems facing date palm cultivation in the Northern region of the Sudan.

The results of this study will contribute to the formulation of a national strategy for the conservation and sustainable use of date palm genetic resources in Sudan. This study suggests further studies to identify the origin of the seedling cultivars/farmers' varieties (Jaw and males).

Keyword: Date palm, River Nile (RN), Northern State (N), morphological characterisation, molecular marker, Simple sequences repeat marker, SSR, genetic diversity


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Contents

1. Introduction

The date palm (*Phoenix dactylifera* L.) was perhaps the first fruit tree cultivated by man. It has been cultivated around the Arabian Gulf since 3000 B. C. or possibly 6000 B. C.(Osman, 1984).

Date palm is one of the neglected investigated crops in Sudan. However, limited research has been done to evaluate the genetic diversity of the Sudanese date palm and to characterize the genetic resources.

At present, the main constraints threatening the local genetic resources of date palm in Sudan, especially in the northern region, are diseases and introduction of new date palm cultivars from other countries(Elshibli and Korpelainen, 2008a). This is in addition to other socio-economic factors such as building of new dams along the river Nile that has resulted in flooding of traditional areas for date palm production. However, there have been no effective efforts exerted yet for conservation of date palm genetic resources in Sudan. Therefore, immediate measures need to be taken for studying and conserving the date palm genetic resources, which are highly adapted to local conditions and can be of value for present and future utilization at national and international levels.

1.2. Background

1.2.1. Date palm Taxonomy and biology

The date palm (*Phoenix dactylifera* L.) is perennial and diploid (2n =2x = 36) and belongs to the genus *Phoenix*, which is the single member of tribe *Phoeniceae*, monocotyledonous family *Palmae.* "Phoenix", which means purple or red in the greek language, refers to the colour of the fruit and "dactylifera" means finger, referring to the fruit appearance or shape (Chao and Krueger, 2007). *Phoenix* species have two forms of growth habit: trunked or clumping. Both forms are common in Sudan where the male trees are trunked and female trees have both forms depending on the culture where the date palm grows. The trunk height is ranging between 15 and 25 meters (Al-Shahib and Marshall, 2003). *Phoenix* species can be distinguished from other palms by having feather-type leaves through modification of the basal leaflets into spines, the presence of a terminal leaflet and a central fold or ridge on the leaflets, which cause the leaflets

to remain erect at all times. *Phoenix* species are dioecious, with the inflorescences arising among the leaves. The small pale yellowish flowers are borne singly, with the sepals being united into a cupule. There are three petals. Female flowers have three carpels, only one of which matures; male flowers generally have six stamens. The fruits of *Phoenix* species are drupes of variable size, depending on the species, with a single grooved seed.

1.2.2. Date palm economic importance

The date palm is unique in providing many uses besides the fruit, which is a stable and dependable food that has long been used in different ways. Fruits are mostly eaten fresh, dried or pounded into pastes, or fermented to produce alcohol or vinegar. Other parts used include seeds, bunch stalks, leaves, fibers, fresh sap and stem longs, each of them has a multiplicity of uses(Osman et al., 1974). Date production in the world reached about 6.6 million metric tons (MT) of fruit in 2010, of which 119 048 tones were produced by Sudan accounting to about 5.5% of the total world production(FAOSTAT, 2010). The date palm in Sudan is grown in an area of about 36 204 ha.

1.2.3. Date palm geographical distribution

The spread of date palms from the place of origin to other areas is believed to have taken place by means of seeds. At present, the date palm zone extends between latitude 10° and 35° north and south of the equator. The limiting factors for its production beyond this zone are rain and high relative humidity towards the equator and low temperatures in the north and south of latitude 35° (Osman, 1984). The date palm culture in Sudan is concentrated along the River Nile banks between latitudes 15.5° and 22° N in River Nile and Northern states, although some isolated date palm populations exist in oasis areas in northern Kordofan, northern Darfour and in the eastern region of the country (Elshibli and Korpelainen, 2009a; Yousif, 1995).

1.2.4. Date palm propagation

The date palm is propagated by seeds, off-shoots and tissue culture. However, being a dioecious species, it is mainly propagated vegetatively by off-shoots to produce plants that are true to type. Propagation by seeds results in new genotypes, and hence constitutes a major source of variation in date palms.

1.2.5. Date palm cultivars in Sudan

Date palms in Sudan has traditionally been grown using old, local cultivars, mainly of the dry type, for 3000 years. However, semi dry and soft cultivars are also grown in limited areas and numbers. The classification of date palm fruits into dry and soft types, mainly depending on the texture of the ripe fruit, is related to some specific content of water and different form of sugars as well as the sugars acidity (Elshibli and Korpelainen, 2009b).The most important indigenous dry and soft cultivars known include (Barakawi, Gondaila, Tamoda and Abdel Rahim) and (Mishrig Wad Khateeb, and Mishrig Wad Laggai) respecti. Moreover, a large number of farmer' verities resulting from seeds are also locally grown by farmers and they are named collectively as Jaw indicating that they are seedling varieties. This is in addition to a number of males that are used as source of pollen for hand pollination of the female trees. Studies on the diversity of such germplasm have so far been limited (Osman and Boulos, 1978).

1.3. Genetic markers

Genetic markers represent genetic differences between individual organisms or species and they do not represent the target genes themselves but act as signs or flags (Collard et al., 2005). There are three types of genetic markers:

(1) Morphological markers which are considered as phenotypic traits or characters. The most common morphological or phenotypic characters used for the date palm are the morphology of leaves, spines and fruits, mainly based on the characterisation of introduced date palm cultivars

in California (Nixon, 1951). Such morphological features are sensitive to environmental factors and can be observed only in mature trees (Elshibli and Korpelainen, 2009a).

(2) Biochemical markers, which include allelic variants of enzymes (isozymes).

(3) DNA markers, which reveal sites of variation in DNA (Winter and Kahl, 1995). DNA markers are the most commonly used markers used nowadays (Leijman, 2011) and they arise from different classes of DNA mutations(Paterson, 1996). These markers are nutria selective as they are usually located in non-coding regions of DNA. There is another type of markers called expressed sequence tags (ESTs) which are developed from expressed regions in the genome. The EST databases can easily be screened for SSRs and SNPs so that specific primers can be designed to investigate the polymorphism. Other classes of markers were developed by designed primers from sequences flanking amplifiable EST segments; these markers were described as expressed tag polymorphism (ESTPs) and can detect both sequence and length. Any markers which have a mean value are called functional markers (FMs). They have effective relationships with traits of interest (Gupta and Rustgi, 2004; Gupta et al., 1999)

Unlike morphological and biochemical markers, DNA markers are in practice unlimited in number and are not affected by environmental factors (Winter and Kahl, 1995). In addition, they have many applications in plant breeding, *e.g.* assessment of genetic diversity levels within a germplasm and verification of cultivar identity. Most of these markers can be used to identify disease resistance genes as well as genes controlling fruit quality traits. They are also used to create genetic maps (mapping of simple traits), and to analyze genetic diversity and relatedness between or within different populations, species and individuals. Generally, marker technology based on polymorphisms in DNA have catalyzed research in different disciplines such as phylogeny, taxonomy, ecology, genetics and plant breeding (Baird et al., 1997; Henry, 1997; Jahufer et al., 2003; Leijman, 2011; Weising, 1995; Weising, 2005; Winter and Kahl, 1995).

1.3.1. Dominant and co-dominant markers

DNA markers are particularly useful to reveal differences between individuals of the same or different species. These markers are called polymorphic whereas markers which do not discriminate between genotypes are called monomorphic.

Polymorphic markers may also be described as co-dominant or dominant and this description is based on whether the marker can detect the differences between homozygotes and heterozygotes. Co-dominant markers indicate differences in size whereas dominant markers are either present or absent (Collard et al., 2005).

1.3.2. Different types of DNA markers

There are many types of DNA markers which have been used in marker analysis, *e.g.* co-dominant RFLP (Restriction Fragment Length Polymorphism) markers (Hartl and Lozovsky, 2005; Winter and Kahl, 1995), Single-Nucleotide Polymorphisms (SNPs) (Schneider et al., 2007), and Simple Sequence Repeats (SSRs) (Hartl and Lozovsky, 2005; McCouch et al., 1997; Powell et al., 1996; Taramino and Tingey, 1996). The dominant markers include Random Amplified Polymorphic DNAs (RAPDs) (Hartl and Lozovsky, 2005; Lynch and Walsh, 1998; Williams et al., 1990) and Inter Simple Sequence Repeat markers (ISSR) (Zehdi et al., 2004b). Amplified Fragment Length Polymorphisms (AFLPs) markers are essentially dominant but co-dominant scoring allows the determination of the presence of one or two alleles at a locus (Ajmone-Marsan et al., 1997; Vos et al., 1995). The advantages of DNA markers are: i) they measure the diversity directly at DNA level (characters are not influenced by the environment and they are independent of the physiological stage of the plant); ii) they have ability to obtain large amounts of data in a short time; iii) they can be used as a non destructive test of polymorphism; iv) they give the possibility to obtain data on non-living material. However, they have disadvantages as well: most of these marker protocols are time consuming and expensive and for some of them the amount of polymorphism is low and the application is complicated (Leijman, 2011; Soliman et al., 2003).

The recent techniques based on polymerase chain reaction (PCR) gives an opportunity for in-depth genetic analysis and construction of linkage maps (Soliman et al., 2003).

1.3.3. Molecular markers in date palm

Few studies have focused on investigating the genetic diversity of date palms by molecular markers. RAPD markers were used to evaluate the genetic diversity among 43 accessions of Moroccan date palms (Sedra et al., 1998). However, low polymorphism was observed in this study. Another study examined the genetic diversity in Tunisian date palms by nuclear microsatellites (Zehdi et al., 2004a). In contrary to the Morrocan investigation, this study showed a high level of polymorphism among the 49 accessions. AFLP markers were used to analyze the Egyptian date palms (El-Assar et al., 2005). A total of 350 bands were scored and 233 (66.6%) were polymorphic in the 47 samples used. The six groups of accessions revealed similar but not identical AFLP profiles suggesting that these accessions might be derived from seedlings rather than through clonal off-shoot propagation. Several other studies have investigated different aspects of the genetic diversity within date palm cultivars (Al-Khalifah and Askari, 2003; Cao and Chao, 2002; Elshibli and Korpelainen, 2008a; Sedra et al., 1998; Soliman et al., 2003).

1.3.4. Simple sequences repeat marker (SSR)

Simple sequence repeat (SSR) molecular markers have been recommended to investigate plant genetic diversity. They are co-dominant, highly polymorphic and highly reproducible (Akkak et al., 2009). Recently, microsatellite markers were used to investigate the genetic diversity and relationship among Sudanese date palm cultivars (Elshibli and Korpelainen, 2008a). Fifty five female accessions representing 37 cultivars collected from different locations in Sudan and eight cultivars collected from Morocco as reference material were analysed at 16 SSR loci. The SSR markers showed a high level of polymorphism with a total of 343 alleles detected. The number of alleles per marker ranged from 14 to 44 with an average of 21.4 per locus. A high level of expected heterozygosity was observed among both Sudanese cultivars (0.841) and Moroccon cultivars (0.820).

1.4. Aim of the study

The objectives of this study were to:

i) Collect and document information on the present status of local date palm genetic resources in the northern region of Sudan (Northern state and River Nile state).

ii) Assess the morphological and molecular diversity of date palm genetic resources in the northern region of Sudan.

iii) Assess the threat level for the existing date palm genetic resources at an on-farm level.

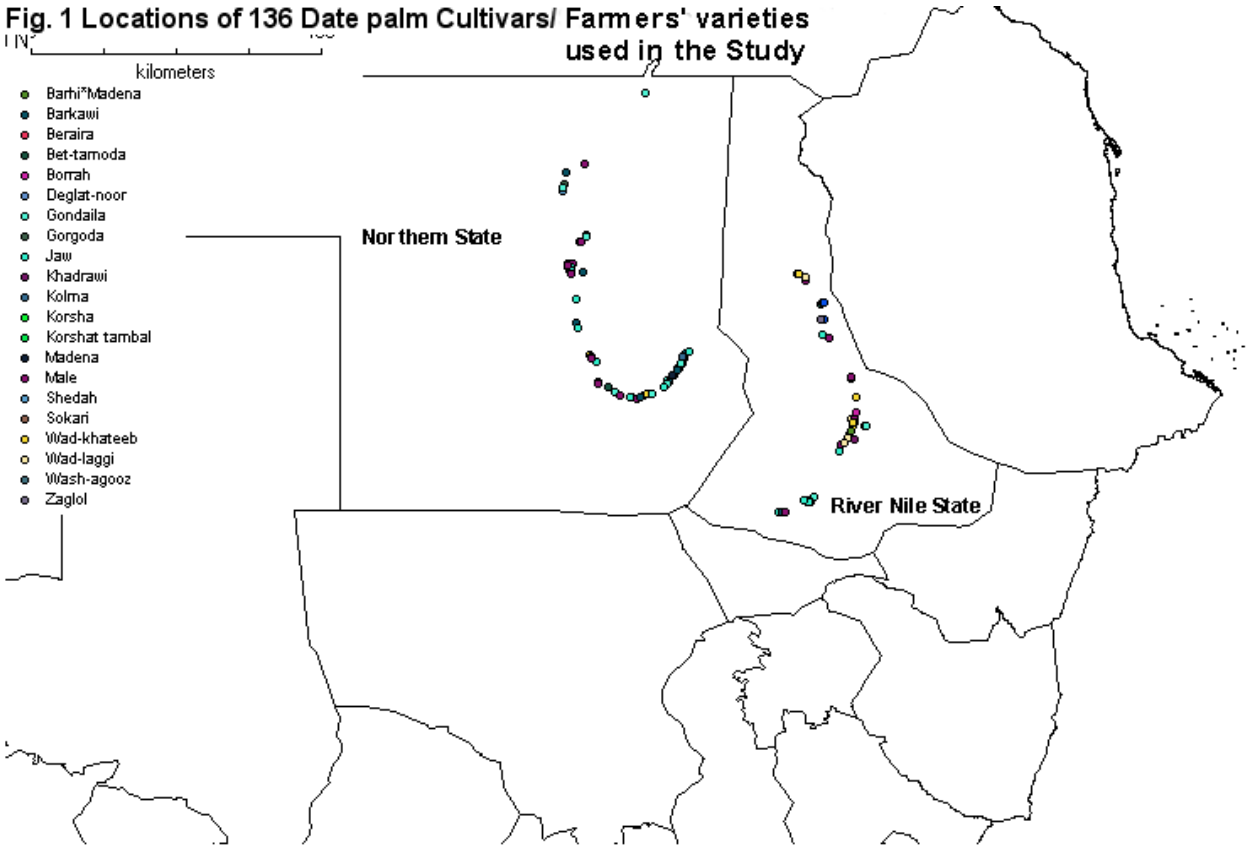
2. Material and methods:

2.1. Collection strategies and sampling methods

The field survey was implemented to investigate the pattern of date palm distribution, assess cultivars used in production and identify constrains and threats. During the survey, farmers and some employees working at the Ministry of Agriculture were interviewed. Plant samples were also collected for further analyses. The two surveyed states were subdivided according to localities and administrative units officially used in Sudan. The total numbers of localities surveyed were 13 of which 7 were in Northern state and 6 were in River Nile state. The newly established locality Al-bohira in River Nile State was not covered in this study as the original date palm populations were submerged by the water of the Merawe dam. The total number of people interviewed in River Nile state was 84, and the total number of people interviewed in Northern state was 131. Thus, the total number of people interviewed in the two states was 215.

2.2. Collection sites

The study has been conducted in Northern region of Sudan including River Nile state and Northern state



2.3. Morphological characterisation

On-farm morphological characterisation of date palms have been conducted using proposed descriptor list (Rizk and El Sharabasy, 2006) . In total, 63 date palm trees were characterized in River Nile and 73 in the Northern state. The total number of characterized date palm trees in the two states was 116 female and 20 male trees (Table 1). Geographical coordinates were recorded using the geographical position system (GPS).

2.3.1 The assessed morphological characters:

(i) Vegetative quantitative characteristics

Trunk diameter, Frond length, Leaf width, Thorn area length, Pinnae length, Pinnae width, Stalk length, Strand length.

(ii) Vegetative qualitative characteristics

Trunk colour, Leaf colour, Midrib colour.

(iii) Fruit quantitative characteristics

Fruit length, Fruit width, Pulp thickness.

(v) Fruit qualitative characteristics

Cultivar group, Fruit colour, Fruit shape, Flesh colour and Flesh taste.

Table 1. Date palm characterized in River Nile and Northern States

Designation	Cultivar	Status	State	Locality	Administrative unit	village	E	N	Elevation
M1	Barkawi	cultivated	N	Aldaba	Aldaba	Abo doom	306774	1988463	249
M2	Deglat-noor	introduced	N	Merawe	Merawe	Abu doom	375234	2043146	261
M3	Wad-laggi	cultivated	N	Merawe	Merawe	Abu doom	375234	2043146	261
M4	Bet-tamoda	cultivated	N	Dongola	Alhafeer	Akoad	223931	2175398	225
M5	Gondaila	cultivated	N	Merawe	Alshohada	Alarak	353171	2013025	268
M6	Wad-khateeb	cultivated	N	Merawe	Karema	Albarkal	377290	2049337	242
M7	Barkawi	cultivated	N	Merawe	Karema	Albarkal	377290	2049337	242
M8	Barkawi	cultivated	N	Merawe	Algurir	Albasa	354353	2010453	245
M9	Gondaila	cultivated	N	Alborgaig	Alborgag	Alborgag	229274	2174614	223
M10		seedling	N	Alborgaig	Alborgag	Alborgag	229274	2174614	223
M11	Gondaila	cultivated	N	Aldaba	Aldaba	Aldaba	283940	1996407	250
M12	Beraira	cultivated	N	Aldaba	Algaba	Algaba	262195	2008987	237
M13	Wad-khateeb	cultivated	N	Aldaba	Algaba	Algaba	261409	2010212	235
M14	Barkawi	cultivated	N	Aldaba	Algaba	Algaba	261409	2010212	235
M15	Madena	introduced	N	Aldaba	Algaba	Algaba	261409	2010212	235
M16		seedling	N	Aldaba	Algaba	Algaba	262195	2008987	237
M17	Bet-tamoda	cultivated	N	Aldaba	Altadamoon	Algabolab	321495	1992480	250
M18	Bet-tamoda	cultivated	N	Aldaba	Aldaba	Algabreia	273680	2004702	237
M19	Wad-khateeb	cultivated	N	Algoled	Algoled	Algoled	251388	2047859	251
M20	Barkawi	cultivated	N	Algoled	Algoled	Algoled gobli	252717	2045582	238

M21	Gondaila	cultivated	N	Merawe	Algurir	Algoriba	352261	2007758	275
M22	Kolma	seedling	N	Merawe	Algurir	Algurir	361221	2019949	265
M23		seedling	N	Merawe	Algurir	Algurir	361221	2019949	265
M24	Korsha	seedling	N	Merawe	Algurir	Algurir	361221	2019949	265
M25	Wad-khateeb	cultivated	N	Aldaba	Altadamoon	Alkolod	325291	1993906	256
M26	Barkawi	cultivated	N	Merawe	Merawe	Alrashedeen	372771	2038969	250
M27	Barkawi	cultivated	N	Dongola	Dongola	Alsahaba	232411	2094375	230
M28	Barkawi	cultivated	N	Dongola	Alhafeer	Alsayala	223466	2170709	230
M29		seedling	N	Aldaba	Altadamoon	Alsyal	313286	1987833	257
M30	Korshat tambal	seedling	N	Merawe	Alshohada	Alzuma	367656	2029199	225
M31	Kolma	seedling	N	Merawe	Alshohada	Alzuma	367656	2029199	225
M32		seedling	N	Merawe	Alshohada	Alzuma	367980	2029003	225
M33	Gondaila	cultivated	N	Alborgaig	Argo	Argo	228457	2161262	237
M34	Barkawi	cultivated	N	Alborgaig	Alborgag	Artigasha	227711	2168578	226
M35	Bet-tamoda	cultivated	N	Alborgaig	Alborgag	Artigasha	227711	2168578	226
M36	Korsha	seedling	N	Alborgaig	Argo	Bayoda	234010	1261482	224
M37	Barkawi	cultivated	N	Alborgaig	Argo	Bayoda	234010	1261482	224
M38		seedling	N	Aldaba	Aldaba	Dabet alfogara	290749	1992629	246
M39	Barkawi	cultivated	N	Aldaba	Altadamoon	Gantti	316084	1990292	240
M40	Jaw	seedling	N	Aldaba	Aldaba	Goshabi	303383	1989706	251
M41	Gondaila	cultivated	N	Aldaba	Altadamoon	Heissain-narti	332589	1993860	247
M42	Jaw	seedling	N	Alborgaig	Alborgag	Karma alnozol	227703	2171767	220
M43	Jaw	seedling	N	Merawe	Algurir	Korti	348943	2003129	264
M44	Barkawi	cultivated	N	Merawe	Alshohada	Magashi	365830	2027155	241
M45		seedling	N	Dongola	Dongola	Maragh	234379	2126372	231
M46	Gondaila	cultivated	N	Dongola	Dongola	Maragh	234379	2126372	231
M47	Jaw	seedling	N	Dongola	Dongola	Maragh	234554	2126176	226
M48	Madena	introduced	N	Merawe	Algurir	Masawe	359062	2018447	247
M49	Gondaila	cultivated	N	Dongola	Alhafeer	Mashoo	226327	2166128	230
M50	Jaw	seedling	N	Dongola	Alhafeer	Mashoo	226327	2166128	230
M51	Jaw	seedling	N	Algoled	Algoled	musenmar	251860	2046982	231
M52	Jaw	seedling	N	Algoled	Dongola alagoz	Nawa	258382	2040146	235
M53	Wad-khateeb	cultivated	N	Merawe	Merawe	Nori	382560	2052407	222
M54	Jaw	seedling	N	Merawe	Merawe	Nori	382560	2052407	222
M55		seedling	N	Merawe	Merawe	Samarate	373635	2036376	254
M56		seedling	N	Dongola	Alhafeer	Saroog	223479	2172843	230
M57	Kolma	seedling	N	Merawe	Karema	Sheba	374386	2045858	247
M58	Gondaila	cultivated	N	Algoled	Algoled	Tamareya	253560	2043874	237
M59		seedling	N	Algoled	Algoled	Tamareya	253560	2043874	237
M60	Gondaila	cultivated	N	Merawe	Merawe	Tangasi	371441	2035182	258

M61	Jaw	seedling	N	Dongola	Dongola	Tate	234583	2085915	223
M62	Barkawi	cultivated	N	Dalgo	Dalgo	Kodorma	248218	2215851	216
M63	Bet-tamoda	cultivated	N	Dalgo	Dalgo	Farag	238418	2205990	216
M64	Kolma	seedling	N	Dalgo	Dalgo	Farag	238418	2205990	216
M65		seedling	N	Dalgo	Dalgo	Gade	241720	2205650	213
M66	Gondaila	cultivated	N	Dalgo	Dalgo	Gade	247469	2213812	216
M67		seedling	N	Alborgaig	Argo	Argo	228457	2161262	230
M68	Gondaila	cultivated	N	Halfa	Halfa	Halfa	326952	2412456	174
M69		seedling	N	Halfa	Abre	Sarkamato	248098	2313383	198
M70	Gorgoda	seedling	N	Halfa	Abre	Kwika	221477	2286151	195
M71	Shedah	seedling	N	Halfa	Abre	Sawarda	218687	2276457	204
M72	Barkawi	cultivated	N	Halfa	Abre	Abre	222984	2302072	192
M73	Gondaila	cultivated	N	Halfa	Abre	Ebood	219031	2282445	203
M74	Abedraheem	cultivated	RN	Abu-hamad	Alsheraik	Abu hasheem	560938	2096286	326
M75	Zaglol	introduced	RN	Abu-hamad	Alsheraik	Abu hasheem	560753	209583	339
M76	Jaw	seedling	RN	Aldamer	Aldamer	Alaliab	582285	1913899	353
M77	Wad-khateeb	cultivated	RN	Atbra	Alfadlab	Albasharab	600953	1948502	354
M78	Gondaila	cultivated	RN	Shandi	Shandi	Albsabeer	500033	1828321	365
M79	Barkawi	cultivated	RN	Shandi	Shandi	Albsabeer	500033	1828321	365
M80		seedling	RN	Shandi	Shandi	Albsabeer	499960	1828438	372
M81	Jaw	seedling	RN	Shandi	Shandi	Albsabeer	499466	1828680	389
M82	Wad-khateeb	cultivated	RN	Atbra	Atbra	Aldakhla	602661	1957745	357
M83	Wad-laggi	cultivated	RN	Atbra	Atbra	Aldakhla	602599	1957504	359
M84	Barkawi	cultivated	RN	Atbra	Atbra	Aldakhla	602578	1957878	355
M85	Barkawi	cultivated	RN	Abu-hamad	Abu-hamed	Algaba	524895	2159956	313
M86	Wad-laggi	cultivated	RN	Abu-hamad	Abu-hamed	Algaba	525308	2159709	313
M87	Wash-agooz	seedling	RN	Almatama	Almatama	Algoba alkromab	536354	1845334	356
M88	Barkawi	cultivated	RN	Almatama	Almatama	Algreaf	505345	1827734	364
M89	Jaw	seedling	RN	Aldamer	Aldamer	Alhasaia	596102	1936920	354
M90	Wad-khateeb	cultivated	RN	Aldamer	Aldamer	Alhasaia	595519	1937505	355
M91		seedling	RN	Aldamer	Alzaidab	Alhawia	584135	1921699	361
M92	Barhi*Madena	hybrid	RN	Aldamer	Aldamer	Alhediba	597838	1941570	352
M93	Jaw	seedling	RN	Barber	Albawga	Almakazen	597925	2017386	340
M94	Jaw	seedling	RN	Almatama	Almatama	Almatama	537934	1845962	363
M95	Wad-khateeb	cultivated	RN	Barber	Barber	Almekharif	605060	1989032	372
M96	Wad-laggi	cultivated	RN	Aldamer	Alzaidab	Almokabrab	592639	1931953	357
M97	Jaw	seedling	RN	Shandi	Shandi	Almouies	540240	1843431	358
M98	Barkawi	cultivated	RN	Shandi	Shandi	Almouies	539898	1844332	358
M99	Wad-khateeb	cultivated	RN	Aldamer	Alatbrawi	Alnashabi	616403	1949233	353

M100	Gondaila	cultivated	RN	Aldamer	Alatbrawi	Alnashabi	617539	1949686	356
M101	Wad-laggi	cultivated	RN	Atbra	Atbra	Alsayala	602916	1958782	356
M102		seedling	RN	Atbra	Atbra	Alsayala	602916	1958782	356
M103	Gondaila	cultivated	RN	Shandi	Shandi	Alshagalwa	548228	1849063	377
M104	Wad-laggi	cultivated	RN	Abu-hamad	Alsheraik	Alsheraik	559938	2075246	339
M105	Jaw	seedling	RN	Abu-hamad	Alsheraik	Alsheraik	559938	2075246	339
M106	Wad-khateeb	cultivated	RN	Barber	Albawga	Altkaween	597121	2013769	343
M107	Barkawi	cultivated	RN	Aldamer	Alzaidab	Alzaidab	588626	1924768	353
M108	Wad-laggi	cultivated	RN	Aldamer	Alzaidab	Alzaidab	588499	1924659	347
M109	Kolma	seedling	RN	Abu-hamad	Alsheraik	Atmoor	556486	2118163	305
M110	Gondaila	cultivated	RN	Abu-hamad	Alsheraik	Atmoor	556486	2118163	305
M111	Bet-tamoda	cultivated	RN	Abu-hamad	Alsheraik	Atmoor	556486	2118163	305
M112	Barhi	introduced	RN	Aldamer	Aldamer	Gandail	601864	1928993	351
M113	Sokari	introduced	RN	Aldamer	Aldamer	Gandail	601864	1928993	351
M114	Khadrawi	introduced	RN	Aldamer	Aldamer	Gandail	601864	1928993	351
M115	Borrah	seedling	RN	Barber	Barber	Kenoor	604996	1966703	351
M116	Wad-khateeb	cultivated	RN	Barber	Albawga	Kilo 6	596837	2017634	349
M117		seedling	RN	Barber	Albawga	Kilo 6	596837	2017634	349
M118	Wad-khateeb	cultivated	RN	Abu-hamad	Abu-hamed	mograd	535872	2151218	315
M119		seedling	RN	Abu-hamad	Abu-hamed	mograd	535872	2151218	315
M120	Wad-khateeb	cultivated	RN	Abu-hamad	Abu-hamed	mograd	535815	2154538	320
M121	Wad-laggi	cultivated	RN	Abu-hamad	Abu-hamed	mograd	535815	2154538	320
M122	Abedraheem	cultivated	RN	Abu-hamad	Alsheraik	Nadi	567677	2070569	343
M123		seedling	RN	Abu-hamad	Alsheraik	Nadi	567677	2070569	343
M124	Barkawi	cultivated	RN	Almatama	Almatama	Salawa	511009	1828061	369
M125		seedling	RN	Almatama	Almatama	Salawa	511009	1828061	369
M126	Wad-khateeb	cultivated	RN	Shandi	Shandi	Shandi	543667	1843216	363
M127	Jaw	seedling	RN	Shandi	Shandi	Shandi foog	542573	1842820	376
M128	Jaw	seedling	RN	Atbra	Alfadlab	Um-altuoor	601341	1952336	351
M129	Wad-khateeb	cultivated	RN	Atbra	Alfadlab	Um-altuoor	601062	1952502	356
M130	Wad-khateeb	cultivated	RN	Abu-hamad	Abu-hamed	Um-eraif	528655	2159393	312
M131	Barkawi	cultivated	RN	Abu-hamad	Alsheraik	Um-gedai	558939	2120604	296

M132	Wad-laggi	cultivated	RN	Abu-hamad	Alsheraik	Um-gedai	558939	2120604	296
M133	Wad-laggi	cultivated	RN	Abu-hamad	Alsheraik	Um-gedai	560436	2118716	336
M134	Wad-khateeb	cultivated	RN	Abu-hamad	Alsheraik	Um-gedai	560436	2118716	330
M135	Abedraheem	cultivated	RN	Abu-hamad	Alsheraik	Um-gedai	560436	2118716	330
M136	Jaw	seedling	RN	Almatama	Almatama	Wad-shetate	534724	1845007	351

2.4. Molecular characterisation

2.4.1. Plant material

The date palm plant material investigated in this study were 75 Sudanese cultivars/ farmers' varieties of which 63 were females and 12 males. 24 female and 3 male cultivars/farmers' varieties were collected from River Nile state and 39 females and 9 males were collected from the Northern state (Table 3).

Young leafs were collected from mature trees, dried and kept on silica gel until DNA extraction.

2.4.2. DNA extraction

Young leaf samples were ground manually with liquid nitrogen. Total genomic DNA was extracted using the DNAeasy Plant Mini Kit (Qiagen) according to the manufacturer's protocol.

2.4.3. PCR amplification

DNA polymorphisms were detected by PCR using 7 SSR primer pairs developed for *Phoenix dactylifera* by (Billotte et al., 2004). Forward primers were labeled at the 5´-end with VIC, HEX, 6-FAM and NED (Table1). PCR reactions were performed in a volume of 20 µl containing 50-70 ng of total genomic DNA, dNTP mix (400 µM of each dATP, dGTP, dCTP and dTTP) and reaction buffer containing 100 mM Tris-HCL (pH 8.8), 500 mM KCl, 0.1% Tween 20 and 15 mM $MgCl_2$. For primers CIR 048 and CIR 063, the double amount of dNTPs and buffer containing 200 mM Tris-HCl (pH 8.55), 160 mM $(NH_4)_2SO_4$, 0.1% Tween 20 and 20 mM $MgCl_2$ was used.

The reaction mixture contained 5 µM of each reverse primer and fluorescently labeled forward primer and 1.2 units of Taq polymerase. An optimization step was performed on 8 randomly selected individuals in order to find optimal amplification conditions for each primer. The PCR programme for each primer is presented in Table 2.

Table 2 SSR Primer pairs and PCR programmes

Primer	Primer sequences (5'-3')	Start	Denaturation	Annealing	Elongation	Final extension
CIR 010	F:6-FAM) ACCCCGGACGTGAGGTG R:CGTCGATCTCCTCCTTTGTCTC	4 min, 94 C°	45 s, 94 C°	59 C°	1 min 72 C°	8 min 72C°
CIR 025	F:(VIC) GCACGAGAAGGCTTATAGT R: CCCCTCATTAGGATTCTAC	4 min, 94 C°	45 s, 94 C°	50 C°	1 min 72 C°	8 min 72C°
CIR 048	F: (NED) CGAGACCTACCTTCAACAAA R: CCACCAACCAAATCAAACAC	4 min, 94 C°	45 s, 94 C°	56 C°	1 min 72 C°	8 min 72C°
CIR 063	F: (6-FAM) CTTTTATGTGGTCTGAGAGA R: TCTCTGATCTTGGGTTCTGT	4 min, 94 C°	45 s, 94 C°	50 C°	1 min 72 C°	8 min 72C°
CIR 078	F: (VIC) TGGATTTCCATTGTGAG R: CCCGAAGAGACGCTATT	4 min, 94 C°	45 s, 94 C°	52 C°	1 min 72 C°	8 min 72C°
CIR 085	F: (HEX) GAGAGAGGGTGGTGTTATT R: TTCATCCAGAACCACAGTA	4 min, 94 C°	45 s, 94 C°	52 C°	1 min 72 C°	8 min 72C°
CIR 090	F: (HEX) GCAGTCAGTCCCTCATA R: TGCTTGTAGCCCTTCAG	4 min, 94 C°	45 s, 94 C°	50 C°	1 min 72 C°	8 min 72C°

Each program was run for 35 cycles. Samples were kept at 4 C° after finishing the amplification programme.

Table 3. Samples collected from River Nile and Northern states of Sudan used for molecular characterisation in this study

Cultivars name	Sex	State	Locality	Administrative unit	Village	N	E
Madena*Barhi	female	RN	Aldamer	Aldamer	Alhediba		
	male	RN	Barber	Albawga	Kilo 6	596837	2017634
Wad-khateeb	female	RN	Aldamer	Aldamer	Alhasaia	595519	1937505
Wad-Khateeb	female	RN	Brbar	Albawga	Altkaween	597121	2013769
Gondela	female	RN	Aldamer	Alatbrawi	Alnashab	617539	1949686
Wad-laggi	female	RN	Atbra	Atbera	Alsaiala	602916	1958782
Jaw	female	RN	Shendi	Shendi	Albasabeer	499466	1828680
Gondela	female	RN	Shendi	Shendi	Alshagalwa	548228	1849063
Wad-Khateeb	female	RN	Atbra	Alfadlab	Um-Altuoor	601062	1952502
Wad-Khateeb	female	RN	Shendi	Shendi	Gorash	543667	1843216
	Male	RN	Shendi	Shendi	Albasabeer	499960	1828438
Wad-laggi	female	RN	Aldamer	Alzidab	Almokabrab	592639	1931953
	Male	RN	Aldamer	Alaliab	Alhawia	584135	1916990
Khadrawi	female	RN	Aldamer	Aldamer	Gandail	601864	1928993
Sokari	female	RN	Aldamer	Aldamer	Gandail	601864	1928993
Barhi	female	RN	Aldamer	Aldamer	Gandail	601864	1928993
Jaw	female	RN	Shendi	Shendi	Shendi-fog	o54257	1842820
Wash-agooz	female	RN	Almatama	Almatama	Algoba	536354	1845334
Jaw	female	RN	Almatama	Almatama	Wad-shtait	534724	1845007
Barkawi	female	RN	Shendi	Shendi	Moias	539898	1844332
Zaglol	female	RN	Abu-Hamed	Alsheraik	Abu-hasheem	560753	2095831
Soltaniah	female	RN	Abu-Hamed	Alsheraik	Atmoor	556486	2118163
Barkawi	female	RN	Abu-Hamed	Abu-Hamed	Algoba	524895	2159956
Barkawi	female	N	Marawi	Karima	Albarkal	377920	2049337
Bet-Tamoda	female	N	Aldaba	Aldaba	Algabria	273680	2004702
	male	N	Dongola	Dongola	Maragh	234379	2126372
	male	N	Aldaba	Altadamon	Alsayal	313286	1987833
Barakwi	female	N	Aldaba	Altadamon	Gantti	316084	1990292
	male	N	Alborgag	Alborgag	Alborgag	229274	2174614
Gondela	female	N	Aldaba	Altadamon	Hessain-narti	332589	1993860
Barakwi	female	N	Aldaba	Aldaba	Abu-Doom	306774	1988463
Wad-khateeb	female	N	Algoled	Algoled	Algoled	251388	2047859
Jaw	female	N	Marawi	Marawi	Algurir	348943	2003129
Jaw	female	N	Dongola	Dongola	Tate	234583	2085915
Gondela	female	N	Aldaba	Aldaba	Aldaba	283940	1996407
Deglat-Noor	female	N	Marawi	Marawi	Abu-Doom	375234	2043146
	male	N	Halfa	Abre	Sarkamato	248098	2313383
Gondela	female	N	Alborgag	Alborgag	Alborgag	229274	2174614

Gondela	female	N	Dongola	Alhafeer	Masho	226327	2166128
Kolmah	female	N	Marawi	Algurir	Musawe	359062	2018447
	male	N	Aldaba	Aldaba	Dabet-Alfogra	290749	1992629
Barakwi	female	N	Aldaba	Algaba	Algaba	261409	2010212
	male	N	Marawi	Alshohada	Alzuma	367980	2029003
Kolmah	female	N	Marawi	Alshohada	Alzuma	367656	2029199
	male	N	Marawi	Marawi	Samarate	373635	2036376
Gorgoda	female	N	Halfa	Abre	Kwika	221477	2286151
Jaw	female	N	Dongola	Alhafeer	Masho	226327	2166128
Barakwi	female	N	Alborgag	Argo	Bayoda	234010	2161482
Barakwi	female	N	Alborgag	Alborgag	Artigasha	227711	2168578
Jaw	female	N	Alborgag	Alborgag	Karma Alnozol	227703	2171767
Gondela	female	N	Halfa	Halfa	Halfa	326952	2412456
Gondela	female	N	Halfa	Abre	Ebood	219031	2282441
Barakwi	female	N	Dalgo	Dalgo	Kodorma	248218	2215851
Jaw	female	N	Marawi	Marawi	Nori	382560	2052407
	male	N	Marawi	Algurir	Algurir	361221	2019949
Wad-khateeb	female	N	Marawi	Marawi	Nori	382560	2052407
Barkawi	female	N	Algoled	Algoled	Algoled Gobli	252717	2045582
Wad-khateeb	female	N	Aldaba	Algaba	Algaba	261409	2010212
Korsha	female	N	Marawi	Marawi	Algurir	361221	2019949
Gondela	female	N	Marawi	Algurir	Algoriba	352261	2007758
Barakwi	female	N	Marawi	Algurir	Albasa	354353	2010453
Gondela	female	N	Algoled	Algoled	Tamareya	253560	2043784
Bet-Tamoda	female	N	Alborgag	Alborgag	Artigasha	227711	2168578
Barahi	female	N	Alborgag	Argo	Argo	228457	2161262
Bet-Tamoda	female	N	Dongola	Alhafeer	Akaad	223931	2175398
Brakawi	female	N	Marawi	Marawi	Alrashedein	372771	2038969
Jaw	female	N	Algoled	Algoled	Musamar	251860	2046982
Barkawi	female	N	Dongola	Alhafeer	Alsyal	223466	2170709
	male	N	Alborgag	Argo	Argo	228457	2161262
Madina	female	N	Aldaba	Algoba	Algoba	261409	2010212
Korsha	female	N	Alborgag	Argo	Bayod	234010	2161482
Wad-khateeb	female	RN	Abu-Hamed	Abu-Hamed	Mograd	535872	2151218
Barhi*wad-laggi	female	RN	Aldamer	Aldamer	Alhediba	547838	1941570
Barhi* Madiena	female	RN	Aldamer	Aldamer	Alhediba	597838	1941570
Khadrawi	female	RN	Aldamer	Aldamer	Alhediba	597838	1941570

2.5. Statistical analyses

Morphological characters were subjected to univariate analyses with the help of the Ordinary Least Square model of the gretl software (gretl version 1.9.8, copyright © 2000 – 2010 Allin Cottrell and Riccardo "Jack" Lucchetti).

For multivariate analyses the Numerical Taxonomy and Multivariate Analysis System for personal computer (NTSYSpc) package version 2.11L, Copyright © 1996 – 2002 (Rohlf, 2000) was used.

To present genetic relatedness among the analysed genotypes, cluster analysis based on Unweighted Pair Group Method with Arithmetic Average (UPGMA) employing Sequential Agglomerative Hierarchical Nested (SAHN) tree module was performed. The SIMINT module was used to compute the distance matrix that provided measures of the degree of dis/similarity between the farmers' varieties.

The length of the PCR products were estimated with GeneMarker version 2.2.0 software (GeneMarker, 2010).

Genetic diversity parameters: allelic diversity, number of private alleles, number of effective alleles, Shannon index, expected and unbiased expected heterozygosity, were detected by using the GenAlex version 6.41 software (Peakall and Smouse, 2006).

To examine factors which influence the respondents' preferences for the Barkawi cultivar/farmers' variety, the binary logit model was estimated using LIMDEP NLOGIT version 4.0.1 statistical package (Table 22).

To examine factors which might have influenced the respondent's preference for the Barkawi cultivar the binary logit model was applied:

$$\text{Log}\left[\frac{\Pr ob(BARKAWI)}{1-\Pr ob(BARKAWI)}\right] = \beta_0 + \beta_n X_n + \varepsilon \qquad (1)$$

Where, $\Pr ob(BARKAWI)$ is the probability that the respondents prefer Barkawi cultivar/farmers' variety, β_0 is the intercept, β_n a vector of regression coefficients associated with personal characteristics of the respondent X_n and ε_i is the error term which is logistically distributed. The variables that were used in the analysis are presented in (Table 21).

3. Results

3.1. Morphological characterisation

The morphological characterisation was conducted on-farm for 116 date palm female farmers' varieties and 20 male farmers' varieties in River Nile and Northern States including several vegetative and fruit (quantitative and qualitative) characteristics.

The results show that there are highly significant differences among cultivars/farmers' varieties with regard to all characters. Furthermore, the female farmers' varieties recorded a higher mean value of all vegetative quantitative characters than the males (Tables 4 and 5).

Table 4. Mean values, SD, CV and P value of quantitative vegetative characters of 116 date palm female cultivars/farmers' varieties

	Frond length/cm	Leaf width/cm	Thorn area length/cm	Pinnae length/cm	Pinnae width/cm	Stalk length/cm	Strand length/cm
Mean	302.84	62.99	87.21	40.04	2.52	96.38	36.26
S.D	65.87	12.71	29.96	6.61	0.58	29.90	10.25
C.V	0.218	0.20	0.34	0.17	0.23	0.31	0.28
P-Value	***	***	***	***	***	***	***

Table 5. Mean values, SD, CV and P value of quantitative vegetative characters of 20 males' date palm cultivars/farmers' varieties

	Frond length/cm	Leaf width/cm	Thorn area length/cm	Pinnae length/cm	Pinnae width/cm	Stalk length/cm	Strand length/cm
Mean	286.61	58.40	71.70	36.80	2.40	82.83	12.39
S.D	81.76	13.91	27.21	8.50	0.51	27.73	5.52
C.V	0.29	0.24	0.38	0.23	0.21	0.33	0.45
P-Value	***	***	***	***	***	***	***

The following vegetative qualitative characters for female and male date palm farmers' varieties were evaluated: Trunk aspect colour, Leaf colour and Midrib colour. The prevalent colour of trunk aspect in female farmers' varieties was pale (76%) while males were dark, 55% (Tables 6 and 7).

The light green leaf colour was the most common in females, 63%, while the green and light green were equally present in males, 50%.

For midrib colour, light green was most common in female and male farmers' varieties, 90%.

Table 6. Frequency and percentage of vegetative qualitative characters of 116 date palm females

characters	Character description	frequency	(%)
Trunk aspect	Dark	27	24
	Pale	88	76
	Ashy	1	1
Leaf colour	Dark green	10	9
	Green	33	29
	Light green	73	63
Midrib colour	Dark green	4	4
	Glossy green	8	7
	Light green	104	90

Table 7. Frequency and percentage of vegetative qualitative characters of 20 date palm males

Characters	Character description	frequency	(%)
Trunk aspect	Dark	11	55
	Pale	8	40
	Ashy	1	5
Leaf colour	Dark green	0	0
	Green	10	50
	Light green	10	50
Midrib colour	Dark green	0	0
	Glossy green	2	10
	Light green	18	90

Table 8. Mean values, SD, CV and P value of quantitative fruit characters of 116 females' date palm cultivars/farmers' varieties

	Fruit length/cm	Fruit width/cm	Pulp thickness/cm
Mean	3.96	2.51	0.60
S.D	0.78	3.34	0.15
C.V	0.20	1.33	0.25
P-Value	***	***	***

The following fruit quality characters were evaluated in 116 date palm females: fruit colour, fruit shape, flesh colour, flesh taste and cultivar group. We could find shiny red, yellow and green fruits. However, the dominating fruit colour was yellow, found in 90 females (78%), while the green fruit colour only had one (1%) female farmers' variety (Borrah). The elliptical fruit shape was found in 30 individuals (26%) while the obviate-elongated was the least spread fruit shape and was only found in 6 females (6%). The most common flesh colour was cream, found in 82 females (71%), while the least occurring was whitish yellow, found in 2 females (2%) (Wad-agooz and Jaw) and whitish creamy, found only in one female farmers' varieties (1%) (Korsha). The delicious-sweet taste was the most abundant flesh taste recorded among 83farmers' varieties (72%) while the palatable was the least prevalent, found in 5 farmers' varieties (5%) (4 Jaws and Gondaila). The most common date type observed in this study was dry (64%) while the semi-soft was the least 15% (Table 9).

Table 9. Frequency and percentage of qualitative fruit characters of 116 date palm females

Fruit characters	Character description	Number of individuals	Frequency (%)
Fruit colour	Shiny red	19	17
	Dark red	6	6
	Yellow	90	78
	Green	1	1
Fruit shape	Cylindrical	15	13
	Elliptical	30	26
	Falcoid-elongate	11	10
	Ovate-elongate	17	15
	Obviate-elongate	6	6
	Ovate	20	18
	Obviate	17	15
Flesh colour	White	31	27
	Whitish creamy	1	1
	Whitish yellow	2	2
	Cream	82	71
Flesh taste	Palatable	5	5
	Delicious	28	25
	Delicious-sweet	83	72
Cultivar group	Soft	25	22
	Soft and semi-dry	17	15
	Dry	74	64

The dendrogram, based on 116 female farmers' varieties of date palm growing in Sudan according to 5 fruit qualitative characteristics (Fig. 2), shows four major clusters plus three minor clusters at the 1.2 distance level, with no specific geographical distribution.

The first cluster of the major group consists mostly of the dry dates Deglat-noor, Korsha and Jaw. The second and third groups show strong clustering of dry dates with overlapping of Kolma, Korsha, Wash-agooz and Jaw. The fourth shows strong clustering of soft dates.

The first minor cluster is made up of three cultivars/farmers' varieties (Jaw, Korsh and Zaglol) while the second and third clusters consist of one Jaw and Gondaila, respectively.

The dendrogram based on 20 male farmers' varieties of date palm according to vegetative qualitative characteristics (Fig. 3), shows one main cluster plus five minor clusters, with no specific geographical distribution.

The principal component analysis (PCA) based on 18 morphological characteristics shows that the highest percentage and cumulative contribution to the total variation was observed in the trunk aspect, 23%, while the lowest was the cultivar group, 2% (Table 10).

A high percentage of statistic contribution for 5 qualitative fruit characteristics was recorded for fruit colour 33% (Table 11), while the least was cultivar group, 8%.

All most the similar trends of (PCA) analysis have recorded with the 60 females cultivars/farmers' varities.

The trunk aspect recorded the highest percentage of statistic contribution (39%) among three vegetative qualitative characteristics for 20 male farmers' varieties, while the midrib colour had the least, 28%.

Fig 2. UPGMA dendrogram of 116 date palm cultivars/farmers' varieties growing in the Sudan, based on 5 fruit qualitative characters

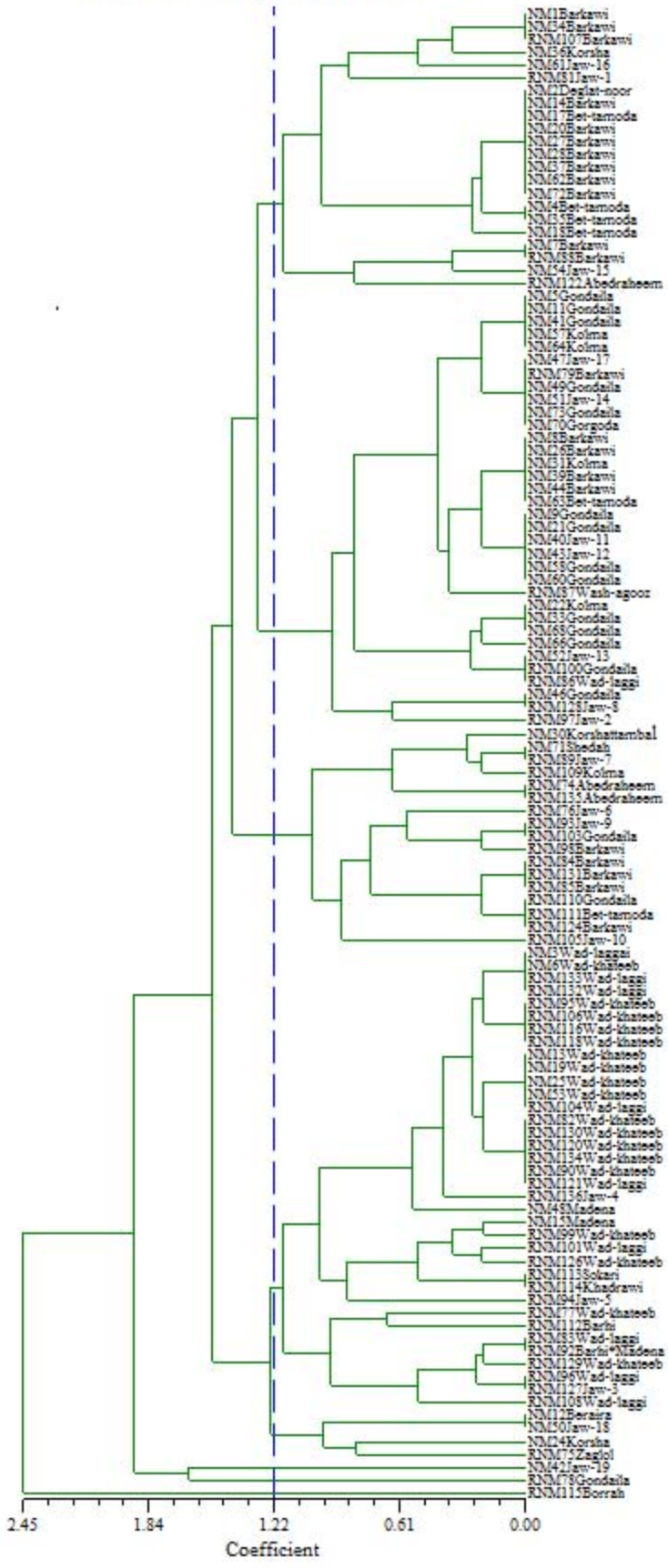


Fig. 3. UPGMA dendrogram of 20 date palm male trees grown in the northern region of the Sudan, based on 10 vegatative characters

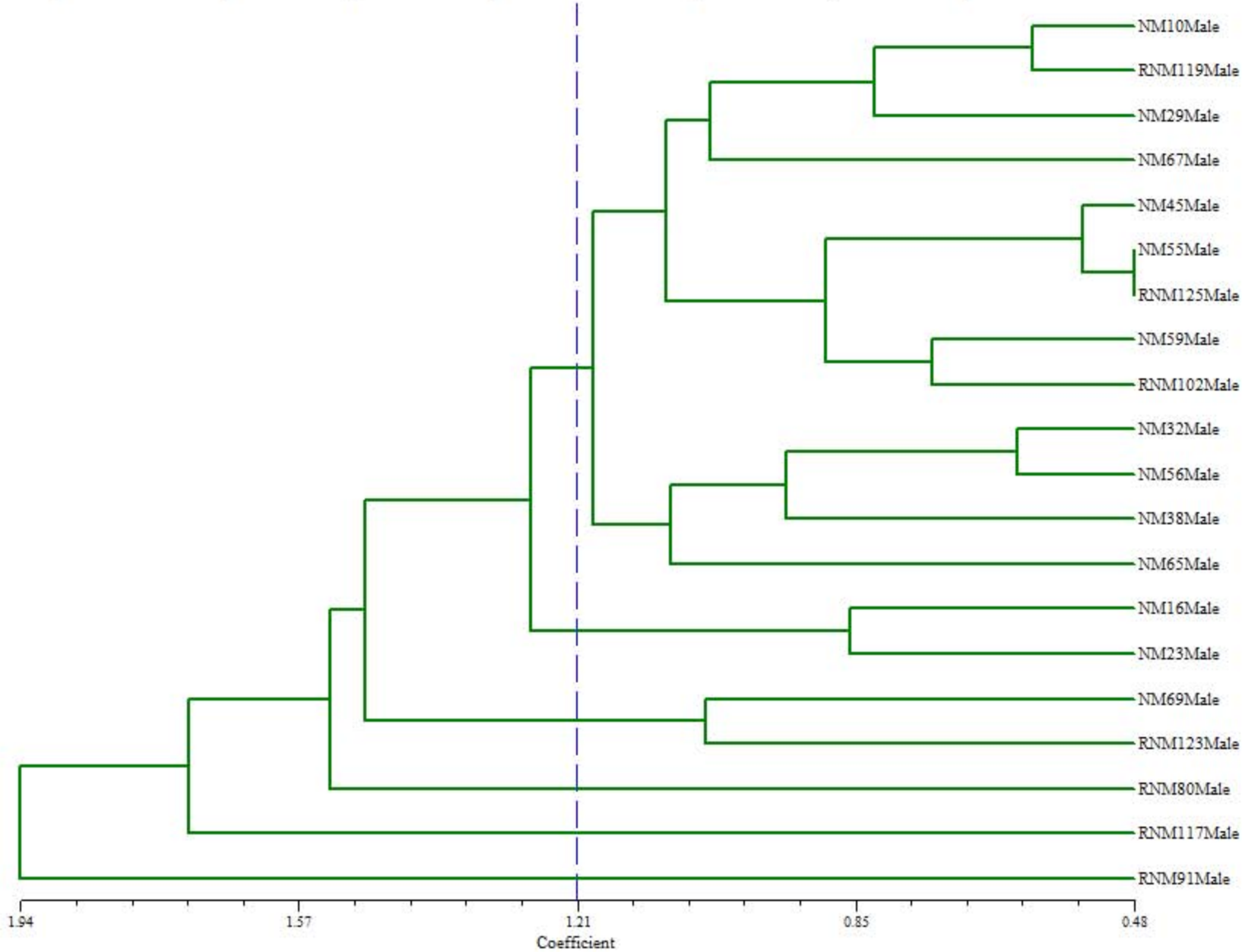


Table 10. Eigenvalue, percentage and cumulative contributions of 18 morphological (quantitative and qualitative) characteristics to the total variation in 116 date palm farmers' varieties, grown in the Northern region of Sudan

Characters	i	Eigenvalue	Percent	Cumulative
Trunk aspect	1	4.06	23	22.6
Frond length	2	2.01	12	33.7
Leaf width	3	1.59	9	42.5
Thorn area length	4	1.43	8	50.5
Pinnae length	5	1.26	7	57.5
Pinnae width	6	1.21	7	64.2
Leaf colour	7	0.94	6	69.4
Midrib colour	8	0.83	5	74.0
Stalkl ength	9	0.80	5	78.5
Strand length	10	0.71	4	82.4
Fruit colour	11	0.59	4	85.7
Fruit length	12	0.52	3	88.6
Fruit width	13	0.50	3	91.4
Fruit shape	14	0.42	3	93.7
Pulp thickness	15	0.36	2	95.7
Flesh colour	16	0.32	2	97.5
Flesh taste	17	0.23	2	98.8
Cultivar group	18	0.22	2	100.0
Sum of eigenvalues	18			

Table 11. Eigenvalue, percentage and cumulative contributions of 5 fruit qualitative characteristics to the total variation in 116 date palm female cultivars/farmers' varieties, growing in the Northern region of Sudan

Characters	i	Eigenvalue	Percent	Cumulative
Fruit colour	1	1.9	33	37.7
Fruit shape	2	1.3	26	63.5
Flesh colour	3	0.8	16	79.16
Flesh taste	4	0.7	13	92.2
Cultivar group	5	0.4	8	100.00
Sum of eigenvalues	5			

Table 12. Eigenvalue, percentage and cumulative contributions of 3 vegetative qualitative characteristics to the total variation in 12 date palm male varieties, grown grown in the Northern region of Sudan.

Characters	i	Eigenvalue	Percent	Cumulative
Trunk aspect	1	1.17	39	38.97
Leaf colour	2	1.00	34	72.30
Midrib colour	3	0.83	28	100.00
Sum of eigenvalues		3.00		

The dendrogram, based on 60 female farmers' varieties of date palm growing in Sudan using five fruit qualitative characters (Fig. 4), shows four main clustering groups plus two minor groups and one unique cluster at 1.12 distance level, with relatively strong geographical relationships. The first group consists mainly of soft dates together with Kolmah and Jaw from RN. The second group was made up of the two Barakawi cultivars/farmers' varieties and Gondela from the same region (RN). The third group showed strong clustering among soft dates, 7 soft cultivars from RN plus 6 soft cultivars/farmers' variety from N. However, Zaglol which is a dry type together with two Jaw belonged to this cluster. The fourth cluster group was made up of a Jaw and a Korsha from N. The fifth cluster showed strong relationships among dry dates of cvs. Gondaila, Barakwi, Jaw and Kolmah from the N and Wash-agooz and Gondaila from RN. The last cluster exhibited strong affinity among Barakawi, Bet-tamoda together with two Jaw and Deglat-noor.

The dendrogram based on 12 male farmers' varieties (Fig. 5) at distance 1.00 showed 6 clustering groups. The first and second group consisted of one individual from RN per cluster. The third cluster showed three males from N, the same as was found in the sixth cluster while the fourth recorded one male from N. The fifth cluster included two males from N together with one male from RN.

Fig. 4. UPGMA dendrogram of 60 date palm cultivars/farmers' varieties growing in the Sudan, based on 5 fruit qualitative characters

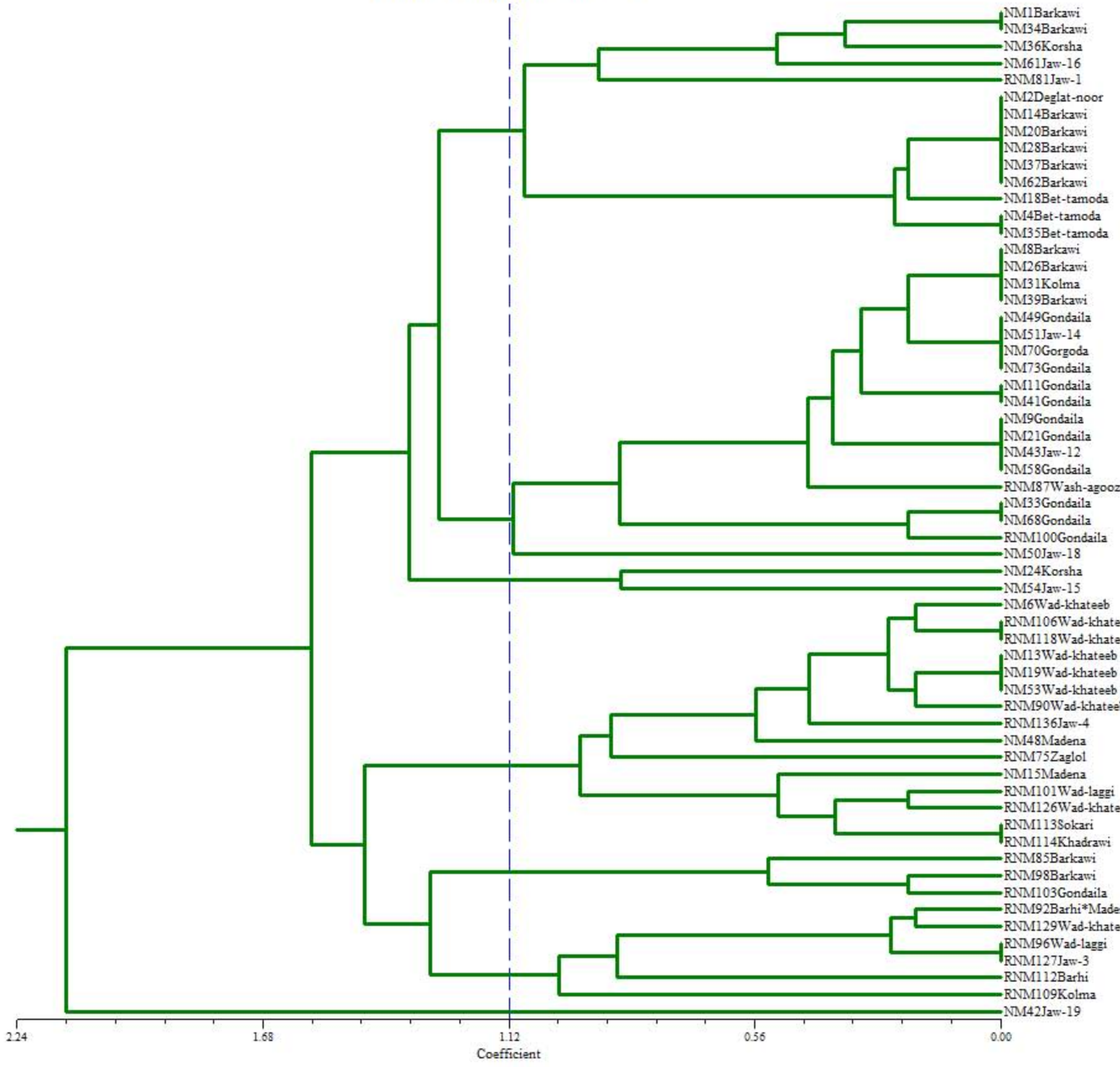
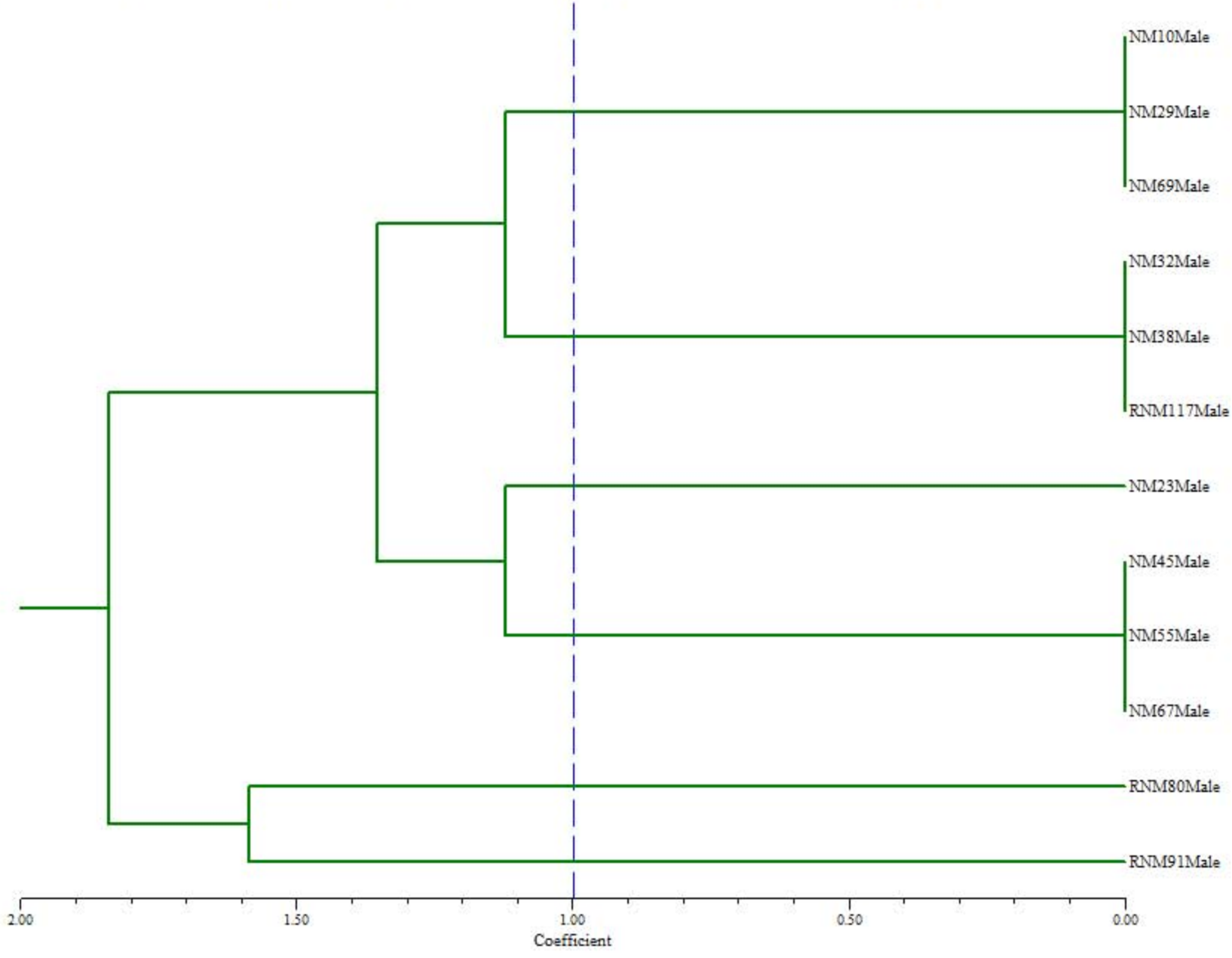


Fig. 5. UPGMA dendrogram of 12 date palm male trees grown in the northern region of the Sudan, based on Trunk aspect, Leaf colour & Midrib colour



3.2. Molecular analyses

The 7 microsatellite primer pairs used to analyze genetic variation in 75 date palm trees collected from Northern part of Sudan (River Nile and Northern States) resulted in a total of 92 alleles with an average of 13.1 alleles per locus. The number of alleles per locus ranged from 8 for locus CIR10 to 17 for locus CIR78 (Table 15). No great differences in genetic diversity were observed among the two groups: Na varied from 9.86 (RN) to 10.43 (N); Ne ranged from 5.52 (RN) to 4.93 (N); I varied from 1.86 (RN) to 1.78 (N). The N cultivars/farmers' varieties showed the lowest value for both He (0.76) and UHe (0.77) while the highest values were observed in RN, He (0.80) and UHe (0.82) (Table13). Mean number of private alleles observed in RN and N was 2.71 and 3.29 respectively (Fig 5).

Table 13. Genetic diversity estimators across analysed groups of date palm cultivars/farmers' variety grown in River Nile and Northern state (mean values)

Group	Number of different alleles,Na	Number of effective alleles,Ne	Shannon's information index,I	Number of private alleles	Expected heterozygosity,He	Unbiased expected heterozygosity,UHe
River Nile State (RN)	9.857	5.517	1.863	2.714	0.804	0.82
Northern State (N)	10.429	4.93	1.781	3.286	0.76	0.768

The PCO shows that the date palm trees in RN and N are diverse and that there is a slight overlapping between them (Fig 7).

The differences between the date palm cultivars/farmers' varieties according to sex (male and female) showed clear differences in genetic diversity between the male (M) and female (F) group (Table 14): Na varied from 12.57 (F) to 7.57 (M); Ne varied from 5.96 (F) to 5.07 (M), while I varied from 1.96 (F) to 1.79 (M). Mean number of private alleles recorded in F and M was 1.34 and 0.57, respectively. The F group showed higher value of He, 0.80 but lower value of UHe, 0.81 while the M group showed the lower value of He, 0.80 and higher value of UHe, 0.83.

The number of alleles was higher in all loci for females compared to males (Table 16).

Table 14. Genetic diversity estimators across analysed groups of date palm cultivars/farmers' variety according to the sex type.

Group	Number of different alleles,Na	Number of effective alleles,Ne	Shannon's information index,I	Number of private alleles	Expected heterozygosity,He	Unbiased expected heterozygosity,UHe
Female	12	5.96	1.96	1.34	0.8	0.81
Male	7	5.07	1.79	0.57	0.8	0.83

Figure 6. Comparison of genetic diversity estimators among two groups of date palm cultivars grown in River Nile and Northern state.

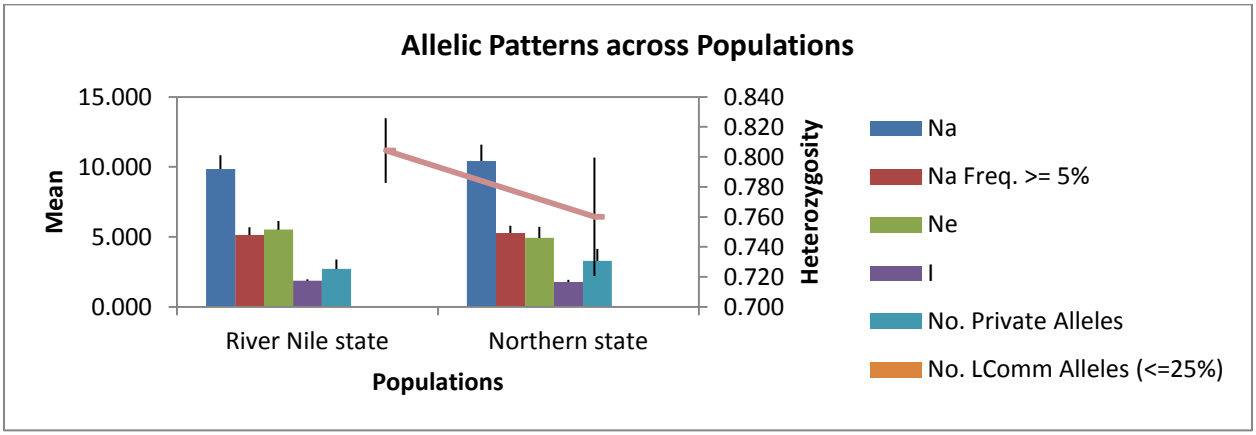


Figure 7. A two-dimensional plot of PCO-analysis of 75 date palm cultivars/farmers' variety growing in River Nile and Northern state

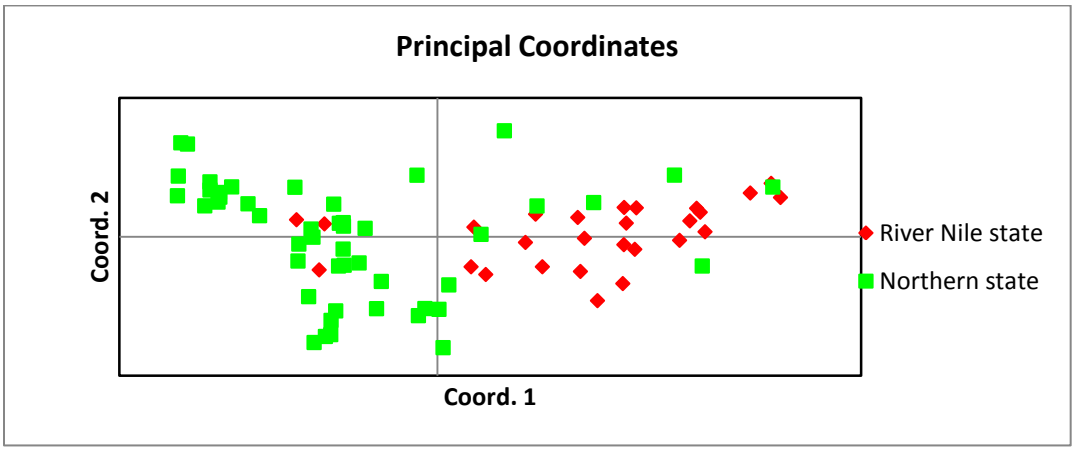


Table 15. Summary of microsatellite allele data revealed by 7 microsatellite loci in 75 date palm cultivars/farmers' variety

Locus number	Locus code	Repeat motif	Allelic range (bp)	No. of alleles	He	UHe
1	CIR10	(AG)22	114–236	8	0.73	0.74
2	CIR78	(AG)13	106–184	17	0.86	0.87
3	CIR25	(AG)22	192–244	11	0.75	0.75
4	CIR90	(AG)26	108–202	10	0.73	0.73
5	CIR63	(AG)17	100–216	16	0.90	0.90
6	CIR85	(AG)29	110–201	16	0.88	0.88
7	CIR48	(AG)32	108–198	14	0.82	0.83

Table 16. Genetic diversity estimators for 7 microsatellite loci calculated for female and male groups

Pop	Locus	N	Na	Ne	I	Ho	He	UHe
Female	CIR10	63	8	3.45	1.50	0.62	0.71	0.72
	CIR78	63	17	7.75	2.32	0.62	0.87	0.9
	CIR25	63	10	3.84	1.57	0.78	0.74	0.8
	CIR90	63	9	3.43	1.55	0.46	0.71	0.71
	CIR63	63	16	9.8	2.45	0.44	0.8	0.91
	CIR85	63	14	7.94	2.28	0.29	0.87	0.88
	CIR48	63	14	5.53	2.06	0.51	0.82	0.83
Male	CIR10	12	7	4.88	1.73	0.67	0.7	0.83
	CIR78	12	10	5.05	1.95	0.58	0.80	0.84
	CIR25	12	6	3.74	1.52	0.5	0.73	0.76
	CIR90	12	6	4.36	1.59	0.5	0.77	0.8
	CIR63	12	9	7.02	2.07	0.5	0.86	0.8
	CIR85	12	8	5.65	1.89	0.25	0.82	0.86
	CIR48	12	7	4.97	1.76	0.42	0.8	0.83

The differences among the date palm according to the fruit grouping type were clearly detected in this study (Table 17).

The mean unbiased expected heterozygosity (UHe) was higher than the expected heterozygosity (He) in every date palm group.

The highest expected heretozygosity was observed in the soft group He=0. 77 while the lowest was found in the dry group (0.73). The highest unbiased expected heterozygosity (UHe) was recorded in the semi-soft group 0.83 while the lowest detected was in the dry group 0.74.

The dry group had the highest mean number of private alleles (1.57) while the lowest were registered in Jaw groups.

The presence of deficit heterozygosity among the date palm groups detected with overall mean value of fixation indices which was 0.30.

Table 17. Genetic diversity estimators across analysed date palm trees according to the fruit grouping type

Pop	Na	Ne	I	No of Private alleles	He	UHe	F
soft	7.14	4.73	1.67	1.43	0.77	0.80	0.37
jaw	6.29	4.32	1.59	0.14	0.75	0.79	0.33
dry	9.14	4.57	1.64	1.57	0.73	0.74	0.18
semi-soft	5.71	4.36	1.59	1.29	0.77	0.83	0.33
Total	7.07	4.50	1.62	1.11	0.75	0.79	0.30

3.2.1 Correspondence between the morphological and molecular results

To verify the correspondence between the morphological and molecular results, we compared the distance matrix from both analyses based on 60 females and 12 males that were common to the two data sets.

The correlation coefficient between molecular diversity and morphological distances was not significant: **r** = 0.003 and P = 0.52

3.3. Social aspects influencing the date palm production

Two hundred and fifteen date palm farmers were interviewed in River Nile and Northern State to investigate current on-farm situation regarding preferred date palm cultivars/farmers' varieties and threats facing date palm culture.

At least 11 date palm cultivars/farmers' varieties can be identified in the study area (Table 19).The most preferred cultivar/farmers' variety was Barakawi while the least preferred farmers' varieties were the Um-dokan, Sakot, Berira, Sagaai and Kolmah.

Table 19 Respondents' preferences for Date palm cultivars/farmers' variety

Cultivar	Respondents (%)
Wadkhateeb	16
Wadlagai	12
Al abd-Alrahim	1.4
Um-dokan	0.5
Sakot	0.5
Barakawi	57
Berira	0.5
sagaai	0.5
Gondala	10
Jaw	2
Kolmah	0.5

The respondents' preferences for date palm cultivars/farmers' varieties in different localities are presented in Table 20. The Wadhateeb and Wadlagai cultivars/farmers' varieties were the most preferred in three localities; The Barakawi cultivar was the most preferred in seven localities, while Jaw and Gondala cultivars/farmers' varieties were the most preferred in only one locality. Of all the localities included in this study the Barakawi was the most preferred cultivar/farmers' variety.

Table 20. Date palm cultivars/farmers' variety preferred in different localities

Locality	Most preferred cultivar
Abuhamed	Wadkhateeb
Aldamer	Wadkhateeb, Wadlagai
Alborgag	Barakawi
Aldaba	Barakawi
Algoled	Barakawi
Almatama	Jawa
Atbra	Wadlagai
Barber	Wadkhateeb
Dalgo	Barakawi
Dongla	Barakawi
Halfa	Barakawi, Gondala
Merawe	Barakawi
Shandi	Wadlagai

Because the Barakawi cultivar is the most preferred it motivated us to explore the factors influencing the respondent's preference for cv. Barakawi as opposed to the other cultivars/farmers' varieties. The variables used in the analysis are presented in Table 21. The factors influencing the respondents preferences for Barakawi was analysed using the binary logit model (Table 22).

Table 21 Descriptive statistics of respondents' characteristics

Variable	Description	Mean	%
BARKAWI	Respondent prefers Barkawi cultivar	-	
	yes=1		57
	no=0		43
FARM_S	Farm size in hectare	8.8	-
DROUT	Drought threatens date palm production	-	
	yes=1		43
	no=0		57
PESTS	Diseases and pests threaten date palm production	-	
	yes=1		52
	no=0		48
EDU	Respondent has at least high school education	-	
	yes=1		63
	no=0		37
YEARS	Number of years that the respondent engaged in cultivating date palm	31	-
	Respondent has cultivated date palm for at least 30 years (median)		
	yes=1	-	43
	no=0		57
INCOME	Annual income from date palm	19,411	-
	Respondent has income of at least 5,000 (median)		
	yes=1		51
	no=0		49
H_SIZE	Household size (number of persons)	7	-
	Respondent has at least household size of 7 (median)		
	yes=1		53
	no=0		47

LOCAL	Locality of the respondent	-	
	Abuhamed and Merawie= 1		33
	Other localities = 0		67

The coefficients associated with drought, diseases and pests, education, and household size had positive and statistically significant effects on the preference for the Barakawi cultivar/farmers' variety. The coefficients associated with farmland size, number of years that the respondent has engaged in date palm farming and the locality of the respondent had negative and statistically significant effects on the preference for the Barakawi cultivar/farmers' variety. The coefficient associated with income was not statistically significant.

Table 22 Binary logit model results for factors influencing preference for Barakawi cultivar/farmers' variety

Variable	Coeff.	SE	T-value	P-value
Constant	-1.071	0.288	-3.721	0.000
Farm_S	-0.012	0.001	-14.877	0.000
DROUT	1.821	0.272	6.701	0.000
PESTS	1.363	0.264	5.157	0.000
EDU	0.929	0.142	6.540	0.000
YEARS	-1.129	0.130	-8.679	0.000
INCOME	0.161	0.128	1.260	0.208
H_SIZE	0.490	0.130	3.757	0.000
LOCAL	-0.545	0.128	-4.254	0.000
Log likelihood function		-992.105		
Restricted log likelihood		-1274.171		
Chi squared		564.131		
Prob[chi squared>value]		0.000		
McFadden Pseudo R^2		0.221		
% correctly predicted		60.679		
Number of observations		206		

4. Discussion

4.1. Morphological characterisation

The phenotypic characterisation conducted to examine the morphological variation among 116 females and 20 males collected from River Nile and Northern States showed significant differences among the 116 female cultivars/farmers' varieties for all morphological characters. These results agree with what was reported by (Elshibli and Korpelainen, 2009b) for Sudanese date palms and (Elhoumaizi et al., 2002) for 24 Moroccan date palm cultivars, especially in vegetative quantitative characters.

The level of morphological diversity in the material is related to genetic or environmental factors, or interaction between the two. In date palm culture the female trees are propagated from shoots and produce true to type clones of their mother plants. However, in this study 31 female farmer varieties, grown are a result of seed propagation in addition to 20 males which are usually seed propagated. According to (Zaid and de Wet, 2002), the mixture of cultivars during sexual propagation by seeds is the main source of variation in the date palm. The differences among the cultivars and especially those between individuals of the same cultivar could be attributed to environmental factors. It was observed during the study that some of the investigated trees were neglected while others were under full care. These differences were clearly noticed in fruit characteristics, e.g. the fruit size is directly affected by cultural practices such as fruit thinning (Obied et al., 2000).Therefore, the fruit size of the neglected date palm trees was smaller than those under full care.

The diversity among 116 females with regard to fruit characters was observed within seven clustering groups (Fig. 2). The overlapping of Jaw, Kholmah, Korsha and Wash-agooz with any clustering group is expected due to the sharing of some characters which have high statistic contributions, such as fruit shape and fruit colour (Table 10) as well as what was found for overlapping of Deglat-noor as semi-soft dates with the first clustering group for dry dates.

The diversity among 60 females with regard to fruit characters was observed within six clustering groups (Figure 4). The overlapping of the Jaw, Kholmah, Korsha and Wash-agooz with any clustering group is expected due the sharing of some characters which have high cumulative contributions to the total variation such as fruit shape and fruit colour (Table 11) as

well as what was found for overlapping of Deglat-noor as semi-soft dates with the fifth clustering group for dry dates (Barakawi and Bet-tamoda). In addition, the intensive exchange of date palm genetic material among farmers in different geographical locations could explain this tendency in different geographical zones. On the other hand, differences i cultural practices, such as fruit thinning and maintenance of date palm male's pollen, where the farmers consider the variety of a potent male's seedling irrelevant and pollinate all their females' inflorescence from the same male (varied from one farm to another, depending on what the farmer believes in). These practices have direct influence on size, shape and colour of the fruits (Swingle, 1928), which can explain the tendency for the same cultivar to be present in different clustering groups, which is true for Barakawi, Bet-tamoda, Gondaila, Wad-khateeb and Wad-laggi. In general, the variability among the date palm fruit characters are expected regarding the presence of more than 400 Sudanese date palm cultivars(Osman, 1984).

The diversity among 12 male farmers' varieties with regard to vegetative quantitative characteristics was observed in six clustering groups (Figure 5). The males M91 and M80 from RN were present in the first and second clusters, respectively, while the male from N did the same in the fourth cluster. Two males from RN ended up as a single cluster because they possessed glossy green midrib colour which had a high statistical contribution. The male M23 from N in the fourth cluster was the only male that possessed the pale trunk aspect, green leaves and light green midrib. The third and sixth cluster groups consisted of three individual males from N in each cluster. The differences between the 3rd and 6th clusters were in leaf colour, where the 3rd group recorded green while the 6th cluster was light green (Table.12). The male M117 from RN was present in the fifth cluster together with 2 males from N.

Generally, the limited number of date palm male trees used (12) gives a poor representation of the genetic diversity level present in date palm male trees in Sudan.

4.2. Molecular diversity

In the present study microsatellite analysis was used to investigate the genetic diversity in 75 date palm samples collected from date palm trees in the River Nile and Northern States of the Sudan. Recently, microsatellite markers were intensively used to investigate the genetic diversity in date palm with contradicting results.

In this study 8 alleles were recorded at locus (CIR10) which is similar to that reported by Zehdi et al. (2004), in Tunisian date palm but less than what Elshibli and Korpelainen (2008a; 2009) found in Sudanese date palm, 12 and 9 alleles, respectively. For the same locus, Billotte et al. (2004) recorded 13 alleles. In locus (CIR78) the number of alleles found was 17 which is higher than that reported by Billotte et al. (2004) and Zehdi et al.(2004) (10 alleles) and Elshibli and Korpelainen (2009) (12 alleles) but much lower than that recorded by Elshibli and Korpelainen (2008a) (23 alleles). Locus CIR85 exhibited 16 alleles which is higher than what Zehdi et al. (2004) and Elshibli and Korpelainen (2009) recorded, 8 and 12 alleles, respectively but less than Billotte et al. (2004) and Elshibli and Korpelainen (2008a) found, 18 and 22, respectively. The number of alleles detected at locus CIR25 was similar to what Elshibli and Korpelainen (2009) found (11 alleles) but lower than what the same authors reported in 2007 (18 alleles). 14 alleles were scored for locus CIR48 which is higher than what Elshibli and Korpelainen (2009) found (9 alleles) but lower than what the same authors recorded in 2008 (26 alleles). 10 and 16 alleles were detected at loci CIR 90 and CIR63, respectively. The number of alleles is similar to that reported by Billotte et al. (2004) for the same locus. However, the number of alleles detected at locus CIR63 was higher than what the same authors found at locus CIR90 (8 alleles). The same loci (CIR63 and CIR90) in this study revealed higher numbers of alleles than what Zehdi et al. (2004) found, 5 and 7 alleles for CIR63 and CIR90, respectively. Elshibli and Korpelainen (2008a, 2009) found 44, 23 and 20, 11 alleles at locus CIR90 and CIR63, respectively. The total number of alleles detected in this study for the 7 loci was 92 which is far lower than the number of alleles reported by Elshibli and Korpelainen (2008a), 177, but higher than the number of alleles reported by the same authors Elshibli and Korpelainen (2009) which is 84 alleles for the 7 loci used in this study.

Table 22 comparing the number of alleles detected in this study with previous studies

Locus code	Elshibli 2007	Elshibli 2009	Zehdi 2004	Billotte 2004	This study
CIR10	21	9	8	13	8
CIR78	23	12	10	14	17
CIR25	18	11	7	6	11
CIR90	23	11	7	10	10
CIR63	44	20	5	8	16
CIR85	22	12	8	18	16
CIR48	26	9		12	14

The mean and the unbiased mean expected heterozygosity (He) and (UHe) were 0.81 and 0.82, respectively, which were lower than those reported by Elshibli and Korpelainen (2008a), 0.85 and 0.91, but higher than what was recorded by Zehdi et al. (2004), 0.70 and 0.61. Although Elshibli and Korpelainen (2008a) attributed the occurrence of higher number of alleles in the Sudanese date palms compared to the Tunisian cultivars to the intensive selection operation in some Tunisian date palms as well as Elshibli and Korpelainen (2008a) reported that the wide range of geographical distribution and the biological nature of the date palm may affect the genetic structure and culture of the date palm. The difference between the present study and that conducted by Elshibli and Korpelainen (2009), is the limited number of representative genetic material used by Elshibli and Korpelainen (2009) which were 15 plants taken from one orchard in Northern State, while in the present study material with a wider genetic base which covered all the Northern part of Sudan (River Nile and Northern State) was used. Therefore, a higher genetic diversity was observed in this study.

The mean number of private alleles in RN and N was 9.71 and 10.57 respectively (Fig. 6). Osman (1983) reported that Sudanese date palm cultivars originated from Northern state. This could justify the higher genetic diversity of the date palm in Northern State compared to that in the River Nile State.

A close similarity level of diversity between males and females was detected in the present study (Table 14), which supports what Elshibli and Korpelainen (2008a) found for 45 females and 23 males of the Sudanese date palm. We expected high unbiased heterozygsity in males (highly segregating) comparing to females However, the results recorded for the limited number of date

palm male trees is not fully representative of the genetic diversity level present in date palm male trees in Sudan. The close similarity could be attributed this to Sudan being a unit regarding cultural practices and exchange of plant material.

The principal coordinate analysis (PCO) showed overlapping between RN and N. The three cultivars/farmers' varieties from RN that interfered with the N group were Jaw, Barkawi and Zaglol (Fig. 7). The source of Jaw is a seed which could be of unknown origin. Barakawi originated from Northern State and was introduced to River Nile. Zaglol is an introduced cultivar from southern Egypt which is much similar to the N group.

Most date palms which belong to the N group that overlap with the RN group was recently introduced from Saudi Arabia by the local Ministry of Agriculture in the Northern State. Furthermore, all those cultivars have high genetic similarity to the soft Sudanese date palm cultivars which are traditionally cultivated in the River Nile State which might explain their tendency to overlap with the RN group.

A difference among date palms according to fruit consistency was observed in this study. The (He) and (UHe) for soft and dry groups was 0.77, 0.80 and 0.73, 0.74, respectively, which is lower than what (Elshibli and Korpelainen, 2008b) found for date palm populations collected from Sudan. The highest mean number of private alleles, 1.57, was recorded for the dry group which explains the higher genetic diversity level in the dry group compared to the other groups. The fixation indices recorded (0.30) is higher than what Elshibli and Korpelainen, (2008a) found (-0.163). These differences might be due to the different sources of genetic material used in the two studies. The source of genetic material used by Elshibli and Korpelainen (2008a) came from date palm seedlings which are highly segregating while the source for the most genetic material used in this study were clones which are true to type to the mother palm (Sakina Elsibili, Department of Agricultural Sciences, University of Helsinki, personal communication).

The diversity level recorded for the Jaw group is not surprising since it is a mixed group (dry, semi-soft or soft) of seed propagated date palms. Hence, they should segregate into different forms of date palms.

4.3. Social

The results revealed that the Barakawi cultivar was widely distributed in the study area which may be explained by the fact that farmers' preferences regarding different cultivars/farmers' varieties reflect the benefits and costs associated with the cultivars. This implies that they prefer cultivars that generate more benefits and discard cultivars that attract costs. The cultivars/farmers' varieties that are rarely distributed, such as Um-dokan, Skot, Berira -sagaai and Kolmah, may be seedlings selected by farmers among self sown plants based on quality criteria. It might be for the farmers' household consumption and never sold. However, the cultivars/farmers' varieties might be endangered due to limitation of exchange and distribution.

Most of the observed localities preferred Wad-Khateeb and Wad-Laggi (soft date palms), especially in localities of the River Nile state. The results support that such cultivars are traditionally grown in this area while the most preferred cultivar in the Northern State localities was Barakawi (dry date palm) which is claimed to originate from this state (Obied et al., 2000).

The results imply that the respondents, who have at least a high school education, and at least seven people in their households and their date palm production threatened by drought, diseases and pests, were more likely to prefer cv. Barakawi. The results could be attributed to the moderate susceptibility of Barakawi to most diseases while the other cultivars are susceptible (Obied et al., 2000) Barakawi is also considered to be one of the most important dry date palms which has the ability for long term storage and is traditionally used as food under long distance travelling. The results showed that respondents who have larger farmland and have cultivated date palms for at least 30 years and belonged to the Abuhamed or Merawe localities were less likely to prefer the Barakawi cultivar. This could be explained by the fact that soft date palms, such as Wadkhateeb and Wadlaggi, are traditionally grown in this area. Some questions in the interview were not statistically analysed.

More than 53% of the respondents considered that the new dam constructed in Merawe had direct effect on date palm cultivation in the region since the climate has changed and the rate of rain increased. On the other hand, in Al-buhira locality, hundreds of thousands of producing and valuable date palms were submerged under the water of the dam reservoir.

Most of the respondents did not know the difference between the local and the introduced cultivars with regard to production and quality because the introduction of them was done recently.

The major problems facing the date palm farmers were drought, pests and diseases, a high taxation level and marketing. Other problems were the lack of agricultural extension services and high costs for fuel, used for irrigation, as well as the total absence of governmental support for date palm cultivation. The civil war in Western part of Sudan, which is the main market area for the date palm, has resulted in the loss of more than 60% of the date palm market.

Most respondents showed positive response to the date palm conservation programme but they insisted that it must be conducted under a joint venture with the government or another organization.

It is important to point out that date palm is not only an income generating source for farmers in the Northern region of Sudan but it is also an old and exciting component of the cultural heritage of people in this region.

5. Conclusion

This study confirmed the high genetic diversity among date palms in Sudan which was reported in previous studies.

The use of morphological characterisation, molecular analysis and interviewing of farmers, assisted in the successful fulfillment of the set of objectives to collect, document and analyze data pertaining to the present status of local date palm genetic resources in the Northern region of Sudan (River Nile and Northern States) with regard to cultivars, production and threats.

The results of this study will contribute to the formulation of a national strategy for the conservation and sustainable use of the date palm genetic resources in Sudan.

Further studies including chloroplast DNA to identify the origin of the seedling cultivars (Jaw and males) are warranted.

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7. Appendices

(I) Characterisation form of date palm

Village name: ……

Coordinates: E:…… N :……

Elevation……

Ad Unit……

Locality……

State……

Date …….

1. Cultivar group
    a. Dry
    b. Semi dry
    c. Soft
2. Sex
    a. Female
    b. Male
3. Trunk aspect:
    a. Dark colour
    b. Pale colour
    c. Ashy colour
4. Trunk diameter:
    a. Slim (<50 cm)
    b. Medium (50-69cm)
    c. Thick (>70 cm)
5. Frond characters
    (a) Frond length…….
    (b) Leaf width (at the middle) (cm)
    (c) Petiole length

(d) Thorn area length……

(e) Pinnae length……...

(f) pinnae width…….

(g) Leaf colour;

i. Dark green
ii. Green
iii. Light green
iv. Ashy green

h. Midrib colour:

i. Dark green
ii. Glossy green
iii. Light green

6. Bunch characters

(a) Stalk length……. (b) Strand length……

7. Fruits characters Khalal stage.

(a) Fruit color

Fruit colour (khalal)	Pale red
	Shiny red
	Dark red
	Pale yellow
	Yellow
	Yellowish red
	Yellow-brown
	Yellow orange
	Orange

(b) Fruit length (average of five fruits) ……

(c)Fruit width (average of five fruits) …….

(d)Fruit shape (Fig)……

(e)Pulp thickness

……

(f) Flesh colour	White
	Whitish creamy
	Whitish yellow
	Cream
	Cream-brown

(g) Flesh taste	Palatable
	Delicious
	Delicious-sweet

(II) Conservation of genetic resources survey

Village name: …….. Date……..

Respondent number……. Gender: Female/Male

I am a student from the Swedish University of Agricultural Sciences. I am interviewing people to know their view concerning local varieties of date palm in relation to their production and conservation.

You are part of the people selected for the interview that will last for between 30 – 45 minutes.

The interview is for research purposes and we would appreciate if you could participate in the interview session.

We assure you that only results for large group shall be reported, but your responses shall be held strictly in confidence. I thank you in anticipation for your cooperation.

Mohamed Elsafi,

SLU.

Personal characteristics of the respondent

i) Are you a native of this village? yes / no

ii) If 'no' to i) how long have you lived in this village? ……. (years)

iii) Mention the number of years you have worked as a farmer ……..

iv) Apart from farming do you engage in any other occupation? yes / no

v) If yes to question IV), please give the name of the occupation…….

vi) What is the size of your farmland? ..... (Fed).

vii) How many crop species do you cultivate on your farm?

(a) 1 (b) 2 (c) 3 (d) More than 3.

viii) Please, mention how many years you have engaged in date palm farming: ……

ix) Educational level: (a) primary (b) high school (c) college / university

x) How old are you ……..

xi) What is the size of your household? ……..

xii) Marital status ……. (a) married (b) single (c) widow (d) divorcee

xiii) What is the average annual income of your household? …… (Sudan Pounds).

Conservation of date palm

1) In your opinion how important is date palm to people in your community?

(a) Very important (b) rather important (c) rather unimportant (d) totally unimportant.

2) Does date palm contribute to your household income? yes / no

3) If 'yes' to question 2), mention how much money your household generated from the

Sale of date palm products last year …….

4) In your opinion what is the major factor that affects production of date palm in your Area? (a) Diseases (b) drought (c) floods (d) scarcity of good varieties of date palm

5) If a new dam is built on River Nile, in your opinion will it affect the production of date? Palm in your area? Yes / no.

6) In your opinion would say that local varieties of date palm has higher yield than the Introduced varieties? Yes / no

7) In your opinion would say that local varieties of date palm produce better quality Products compared to the introduced varieties? Yes / no

8) In your opinion would say that the local varieties of date palm are more resistant to Diseases and pests compared to introduce varieties? Yes / no

9) Assume that a date palm conservation programme is proposed. This may increase the availability of local varieties of date palm to the present generation and successive generations of our society. Since the local varieties are more adapted to our environmental conditions we may require less money to maintain date palm farms and also less crop failures. If the conservation programme require you to set-aside 1% of your farmland to conserve local varieties of date palm would you participate in the programme? Yes / no

If 'no' give reasons ……

……..

……..

…….

If ‘yes’, assuming that it will cost you …… (2, 5, 7.5, 10, 15, 20, 25, 30 Sudan Pounds) yearly for setting-aside 1% of your farmland to conserve date palm will you still participate in the programme? Yes / no.

10) Please, suggest other ways that local varieties of date palm can be conserved in your area:

……

……

……

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