EX HERBARIO RHODESIENSI
(Salisbury — SRGH)
FLORA OF Bechuanaland

District South Eastern Division No.
Alt. Coll. H.Wild & R.B.Drummond
Date 23rd March 1965 Collector's No. 7236

Acacia tortilis (Forsk.) Hayne subsp. spirocarpa (Hochst. ex A.Rich.) Brenan

Between Lake Dow and Chukutsa pan, 18 Km. E of Botletle R. channel

Low stony ridge overlooking large pan with scattered Colophospermum mopane, Boscia rehmanniana, Acacia grandicornuta, Acacia nebrownii etc.

3-4 m. tree

G.P. & S. 15902—20,000—21-7-64. A G 3

HERBARIUM KEWENSE
FROM GOVERNMENT HERBARIUM SOUTHERN RHODESIA

Acacia tortilis (Forsk.) Hayne subsp. heteracantha (Burch.) Brenan

Seen for "Flora Zambesiaca"

COLL. Wild & Drummond 7236. . . 19

THE VARIATION, DISTRIBUTION AND UTILISATION OF ACACIA TORTILIS (FORSK.) HAYNE. LEGUMINOSAE, SUBFAMILY MIMOSOIDEAE.

BY
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A DISSERTATION SUBMITTED IN PARTIAL REQUIREMENT FOR THE MASTER OF SCIENCE IN PURE AND APPLIED PLANT TAXONOMY.

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ABSTRACT

Acacia tortilis (Forsk.) Hayne. a species of the sub-family Mimosoideae in the family Leguminosae is of a future economic importance in the arid and semi-arid lands of Africa and the Middle East. Its variation throughout the continent of Africa and in to the Middle East is immense. The various uses of each part of the plant are known knowledgeable and with further improvement of the plant through research; would boost the economic aspects of this species.

A study on the morphological variation, distribution and utilisation of *Acacia tortilis* was carried out. A close relationship was found to exist in the subspecies of *Acacia tortilis.* Subspecies *heterecantha* and subspecies *spirocarpa* are closely related morphologically but with further research on pods and other taxonomic aspects besides morphology can assist in clarifying the differences. Subspecies *raddiana* is distinct from the rest of the subspecies, although field work and other taxonomic aspects for all the subspecies are necessary to confirm this aspect.

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CHAPTER 1

INTRODUCTION

Acacia tortilis (Forsk.) Hayne. a species of the sub family Mimosoideae in the Family Leguminosae is of particular economic importance in Africa and some parts of Asia. It is also of interest to the taxonomist, ecologist and phytogeographer because of its variation from the southern part of Africa up to the north of Africa and into to Asia. It is a species which is complicated genetically (Anderson and Bell, 1974) and it is divisible into four distinct geographical subspecies. According to the recent classification in Ross's Conspectus of the African Acacia species, (1979) the following subspecies can be distinguished: subspecies tortilis; ~~subspecies~~ heterecantha (Burch) Brenan; Subspecies Spirocarpa (Hochst, ex A. Rich) Brenan; (with two recognised varieties: Var. Spirocarpa and var. Crinita Chiov) and Subspecies raddiana (Savi.) Brenan, (also with two recognised varieties: var. raddiana and var. pubescens A. Chev.). (Ross, 1979)

Acacia tortilis (Forsk.) Hayne. ssp. raddiana is the most distinctive and is regarded by some workers as a separate species (Brenan 1957). Subspecies heterecantha and Spirocarpa are morphologically similar yet ssp. Spirocarpa has some local forms in East Africa which diverge from ssp. heterecantha. Although ssp. tortilis seems to be isolated from the rest; occasionally one or two characters may be associated with either ssp. raddiana or ssp. spirocarpa.

It is suggested that Acacia tortilis spread from the north East tropical Africa to the north of the Continent and in to the Middle East, to the western part of Africa and southwards through East and Central Africa to the northern Cape of South Africa (Burtt,1930). Africa with its diverse microclimates may be playing part in its variation throughout its range, while man, animals and historical factors may be responsible for its distribution. Although the subspecies of Acacia tortilis may seem to be distinct enough as stated above, a number of intermediates occur which may have led Burtt Davy in (1930) to question whether he was not dealing with an "aggregate" species.

Acacia tortilis has no outstanding position in the economic figure of exports or imports of the world yet its importance in the internal economy of arid lands of Africa and the Middle East cannot be under-estimated. The tree is a forage plant for both domestic and wild animals. Gum and tannin are produced from this species in some parts of North West Africa and East Africa, respectively. The wood is used in various ways especially as fuel. These with many other miscellaneous uses may be of future benefit to man.

It is therefore worthwhile to look at the morphological variation, the distribution and utilisation of this species in order to facilitate the work of all people who would be dealing with *Acacia tortilis* in various areas.

Historical background of nomenclature.

Many authors have dealt with the nomenclatural aspects of *Acacia tortilis* and its variants and a summary of this is as follows:

The name *Acacia tortilis* was first published by Hayne in 1827 and he based this name on *Mimosa tortilis* Forskal, which appeared in Flora Aegyptiaco-Arabica, (1775) with a very short description. Pehr (Peter) Forskal a Finish botanist named *Mimosa tortilis* most probably after the Danish Orient expedition in(1761-1763) of which he was a member. He then left a manuscript Flora Aegyptiaco-Arabica which was published later by a botanist called C. Niebuhr (1775). The identity of Forskal's plant on which it was based had long been in doubt, for it seems that the characters given in his description were not sufficient for determination (Bentham 1875). The description is as follows:-

> "*Mimosa tortilis* (Forskal). Hares. Pods contorted. Flowers in heads, white. Pods curled. Leaves bipinnate, 5 pairs. Leaflets 7-9 paired, oblong, extremely short".

Hares was the name of the plant in Arabica; and the plant was collected from Haes in the northern part of Yemen.

According to Hill(1940), Hayne cites Forskal's description and Ehrenberg's specimens. Therefore Hayne's name has continued to be used in the nomenclatural aspects of this species.

However, a plant was found in Ethiopia by Hochestetter (1787-1860), which he named Acacia spirocarpa Hochst. in A. Rich. The description and name were published by A. Richard(1847). This plant had some resemblances with Hayne's plant and this led Bentham in 1875 to consider Mimosa tortilis to be either A.spirocarpa or A. tortilis Hayne. He therefore included Forskal's name as a synonym of A. spirocarpa. In 1927 A. Chevalier questioned the validity of Acacia tortilis Hayne. He discarded the name later and adopted Acacia fasciculata Guillemin and Perrottet, because he could not locate Forskal's specimen, on which the name was based. In 1933 Maire suggested that Forskal's name implied a different species from the one Hayne had described which was by then A.spirocarpa Hochstetter in A. Richard rather than A. tortilis Hayne, and that Hayne had mistakenly applied the original epithet in its new postion. Maire got such a belief because a botanist called Christensen had access to Forskal's herbarium and had produced a report, and therefore was in a better position to accurately pass on the identity of Mimosa tortilis than any other person. Maire therefore adopted Acacia tortilis (Forskal) Hayne to the plant which was passing as Acacia spirocarpa Hochst, ex A. Rich. and Acacia raddiana G. Savi to the plant which was passing as Acacia tortilis Hayne. He therefore dropped Acacia fasciculata Guillemin and Perrottet, since it was also a later homonym of both A. fasciculata Kunth and A. fasciculata R. Brown. Maire did not discard the Forskal name since it had a description which was also accompanied by publication of the name. Acacia raddiana was a species which was named by Savi in 1830 from Egypt which had resemblance with Hayne's plant as well. Therefore before 1930, two species were recognised Acacia raddiana savi and Acacia tortilis (Forskal) Hayne, the former having glabrous pods, larger leaflets and glabrous branchlets and the latter having hairs on pods, rachis of leaves and branchlets. However, after Bakers work on the Legumes of tropical Africa 1930 and Burtt's account in the same year, Acacia tortilis was considered as a complex in tropical Africa, existing as two main species. A. tortilis or A. raddiana with glabrous pods and A spirocarpa Hochst. ex. A. Rich with pubescent pods. A. heterecantha Burch, another species which had been found by Burch in South Africa was put near the above two species by Baker, but still maintaining it as a species, it had glabrous pods but had pubescent vegetative parts. Several intermediate species were found to exist between A. raddiana and A. spirocarpa and already by 1930 some names had been put forward describing these races. However in 1957 Brenan proposed a new scheme where he considered all the species which were suggested to be closely related to Acacia tortilis as subspecies. He proposed the following subspecies:- ssp. tortilis; ssp. raddiana, which exists as two varieties; ssp. heterecantha which occurs in South Africa and ssp. spirocarpa which exists as two varieties. For a summary of synonyms of these subspecies, see table 1. This will express clearly how many stages Acacia tortilis has gone through in achieving the nomenclatural status of today.

LE I THE NOMENCLATURAL STATUS OF ACACIA TORTILIS

ubspecies ortilis	Subspecies spirocarpa var. spirocarpa.	Subspecies spirocarpa var. crinita.	Subspecies raddiana var. raddiana	Subspecies raddiana var. pubescens	Subspecies heterecantha
imosa tortilis orsk., A. egypt-Arab.176 1775).	A.spirocarpa Hochst ex.A. Rich.,Tent. Fl. Abyss. 1:239 1847		A. raddiana savi, Alc. Acazie Egiz. 1.(1830)	A.fasciculata var. pubescens(A.Chev.) A.Chev in Revue, Bot. appl.Agric.trop.8: 127(1928)	A.heterecantha Burch;, Trav.1, 389(1822)
cacia spiro- arpa Hochst. x A.Rich.var. inor schweinf. n Linnaea 35, 3 (1867-8)	A.raddiana var. leguminibus praesertim junioribus pubescentibus Del.ex Ferr.& Galin.,Voy. Abyss.3:118 (1848) A probable synonym.		A.tortilis(non (Forsk.)Hayne, Sens.Strict.) -Schweinfurth in Linnaea 35, 327(1867-8)	A.tortilis var., pubescens.Aylmer ex. Burtt Davy in Kew Bull 1930. 404 (1930) nom.illegit.	A.litakusensis Burch.,Trav.2, 452(1824)
	A petersiana Bolle in Peters, Reise.Hossamb.Bot. 1:4 1861;A.spirocarpa var.major schweinf.in Linnaea 35:323,t.5 (1867-8)		A.fasciculata Guill et Perr. in Guill et.A.Rich.Fl Senegamb.Tent.I 252(1832) Synon.prob.	A raddiana var. pubescens(A.Chev.) A.F.Hill in Bot.Mus. Leafl.Univ.8:103 (1940)	A.spirocarpoides Engl.in Engl., Bot.Jahrb.23(1888)
	A.spirocarpa forma pubescens Terracc. in Annkar.R.Inst.bot Roma 5:110(1893) A.pappii Gandoger in Bull.soc.bot.Fr.60: 458 (1913)		A.tortilis var. Lenticellosa Chiov.,Fl. Somala 2:197,fig 121(1932)nom. invalid.		
	A.tortilis sensu B.D Burtt in J.Ecol.30:93 (1942)A. tortilis forma spirocarpa (Hochst.ex A.Rich) Roberty in Candollea 11 144(1948)		A.tortilis(Forsk) Hayne.f. raddiana (savi)Roberty in Candollea 11,143 (1948)		A.maras Engl in Engl.,Bot. Jahrb.10,24 (1888)

The Key to the most recent infraspecific classification of *Acacia tortilis* (Ross 1979)

Pods glabrous or nearly so, eglandular:
- Young branchlets, petioles and leaf rachides glabrous or subglabrous .... ssp. *raddiana* var. *raddiana*
- Young branchlets, petioles and leaf rachides shortly pubescent........ ssp. *heterecantha*

Pods oppressed - puberulous to tomentellous or pubescent, glandular or eglandular:
- Pods 3-5mm wide, shortly pubescent, eglandular........ ssp. *tortilis*
- Pods 6-13mm wide, oppressed-puberulous to tomentellous or pubescent:
  - Pods oppressed-puberulous, eglandular, (6) 7-9mm wide........ ssp. *raddiana* var. *pubescens*.
  - Pods tomentellous or pubescent with spreading or curved hairs, among which are numerous dark red glands clearly visible through a hand lens, 6-9 (13)mm wide:
    - Pods densely tomentellous or pubescent, hairs mainly short and less than 1mm long but scattered long hairs sometimes also present........ ssp. *spirocarpa* var. *spirocarpa*
    - Pods densely clothed with whitish spreading hairs 1-3mm long........ ssp. *spirocarpa* var. *crinita*.

CHAPTER 2

THE VARIATION OF Acacia tortilis

2.1 INTRODUCTION

Various work has been carried out on some subspecies of Acacia tortilis in the areas of Cytology (Vassal 1974), anatomy (Robbertse 1975, Fahn 1959), morphology (Brenan 1957, 1959, Ross 1979), ecology (Burtt 1930, Elamin 1976), phytogeography (Eig 1931, Zohary, 1962, Halevy 1974), phenology (Halevy and Orshan 1973), entomology (Halevy 1974, Southgate 1978) and Chemistry (Anderson and Bell, 1974).
However, inspite of such works, Acacia tortilis remains a problematic species because subspecies raddiana is still maintained as a species by some workers and the morphological difference between ssp. spirocarpa and ssp. heterecantha cannot be defined in some geographical areas. The following morphological study is an attempt to look at the variation that exists in Acacia tortilis in view of the above problems.

2.2 Materials and methods

A morphological study was carried out on herbarium materials of Acacia tortilis (Forsk.) Hayne. ssp. tortilis; ssp. heterecantha; ssp. spirocarpa var. spirocarpa and var. crinita; ssp. raddiana var. raddiana and var. pubescens. All the specimens studied are housed at the herbarium of the Royal Botanic Gardens, Kew. The specimens were examined and the types were studied. The distribution, habitats and uses were noted from the herbarium specimens and from the Literature cited at the end of this work. Specimens of the same subspecies were studied from different localities to give a full range of variation of the taxa. In all, about 240 specimens were studied from the herbarium. Various works on the _Acacias_ of Africa by Brenan (1957,1959.) together with the recent work of Ross(1979)on the African _Acacias_ were frequently referred to especially the nomenclature and synonyms which were well covered by both workers. The description of the species covers practically all the ranges of variations in the specimens which were examined. Selected specimens for drawings and graphs are cited at the end of the work and some within the text. The choice of specimens is arbitrary since it is impossible to include all the specimens studied. However, for purposes of consultation, the specimens are housed at the herbarium of the Royal Botanic Gardens Kew.

The results have been summarised in table 2 for comparison, the description and discussion follows later. Results The quantitative characters were recorded and graphed in Scatter diagrams to show the quantitative relationships of the parts of plants. However, not all the different subspecies were fully represented with all the morphological parts, few graphs were drawn according to the fully represented morphological characters. Scanning electron photographs of the surface of pods were done in addition with

TABLE 2: The summary of the morphological characters of *Acacia tortilis* subspecies *heteracantha*, ssp. *tortilis*, ssp. *spirocarpa* var. *spirocarpa*, var. *crinita*; ssp. *raddiana*, var. *raddiana* and var. *pubescens*.

Subspecies / characters	ssp. tortilis	ssp. spirocarpa var. spirocarpa	ssp. spirocarpa var. crinita	ssp. heteracantha	ssp. raddiana var. raddiana	ssp. raddiana var. pubescens
Habit	Shrub 1-4 meters	Shrub or tree 4-10(18) meters	shrub/bush/ tree 3-12 meters	Tree or shrub 3-5(12) meters	Tree 3-9 meters	Tree 3-9 meters
Crown	Obconical	Flat and spreading	Flat	dense and compacted flat crown	round	more or less round
Habitat	Stony sandy clay soils	Brown grey compacted alluvial sandy loam	Chestnut brown soils or eroded stony sandy loam	sandy loam, shallow gravelly sandy loam grey powdery blackish alluvial soils	Gravelly sandy loam soils orange brown laterite soils	Gravelly sandy loam
Stems from base	Many stems	2-3	1-2	1-3	1	1
Bark	longitudinally fissured, almost smooth yellow to brown-grey	longitudinally fissured. Thick and dark grey	longitudinally fissured. Grey	longitudinally fissured. Dark grey/dark brown, rough and thick.	narrow fissures almost smooth Reddish brown	Greyish slash green with red tints
Young branchlets	Yellowish grey densely and very shortly pubescent (gives a woollen type of appearance) lenticelled	pale brownish yellow. shortly pubescent lenticelled	redish brown densely pubescent with long white and silvery hairs more than 2mm long lenticelled	light brown grey. Shortly and sparsely pubescent lenticelled	Dark red glabrous and smooth. lenticelled	Dark red glabrous to sparsely pubescent. lenticelled
Spines	Short dark brown and recurved 3mm long and the long white grey slender ones. 2-3cm	short brown and recurved 2-3mm long and the long dark greyish ones 1.5-3.5 cm. long. rare.	short brownish red and recurved 2-3mm long and the long greyish white ones 2-3cm long. rare.	short brown black and recurved. 3-4mm long and the straight long white ones 2-4.5cm	short grey and recurved. rare. 3-6mm long and the long slender and smooth white ones 3-8cm long very common and many.	short grey-brown and recurved, rare. 2-4mm long and the straight slender and white ones 3-6.5cm long common;
Leaves length	bipinnate less than 2.5cm long	bipinnate 2.5-4cm long	bipinnate 2-3.5cm long	bipinnate 3.5-4.5cm long	bipinnate 3-5cm long	bipinnate 3-4cm long
Petiole	3-5mm very shortly pubescent with a woollen appearance	4-8mm shortly pubescent	3-6mm pubscent (long silvery hairs)	2-8mm shortly and sparsely pubescent	4-8mm glabrous	3-7mm glabrous to slightly shortly pubescent
Rachis length	1.5cm or less	1.5-3cm	1-2.5cm	2.5-3.5cm	2-4cm	2-3cm —
Number of Pinnae pairs	3-5	5-10	4-5	5-10(13)	2-5(10)	4-5
Rachillae length	3-7mm very shortly pubscent	6-12mm shortly pubescent	4-6mm sparsely pubescent (long hairs silvery in appearance)	8-10mm glabrous to pubescent	2-17mm glabrous	3-10mm glabrous to pubescent
Number of leaflet	8-12	11-18	9-12(15)	15-17(19)	6-15(19)	7-18

Subspecies / Characters	ssp. tortilis	ssp. spirocarpa var. spirocarpa	ssp. spirocarpa var. crinita	ssp. heteracantha	ssp. raddiana var. raddiana	ssp. raddiana var. pubescens
Leaflet length	2-3mm	3-4mm	3-4mm	1-5mm	3-5mm	3-4mm
Leaflet	Oblong/obovate	oblong/ oblanceolate	oblong	oblong	oblong/obovate	oblong
Leaflet indumentum	very shortly pubescent (woolien in appearance)	glabrous to shortly pubescent	glabrous	glabrous to pubescent	glabrous	glabrous to slightly pubescent
Inflorescence	3-4mm diameter	4-7mm diametor	3-7mm diameter	3-6 diameter	6-10 diameter	3-4mm diameter
	Pale yellow and sweet scented	cream to pale yellow sweet scented	deep yellow and sweet scented	white to pale yellow sweet scented	dirty white to pale yellow sweet scented	pale yellow sweet scented
Peduncle length	1-1.5cm	1.5-2.5cm	0.5-1cm(2.5cm)	(1)2-2.5(4)	1-2.5cm	1.5cm-2cm
indumentum	shortly pubescent	densely pubescent	densely pubescent	sparsely pubescent	glabrous	glabrous
Flower	bisexual	bisexual	bisexual	bisexual	bisexual	bisexual
Petals	yellow and 1mm	yellow & 2mm	yellow & 2mm	yellow & 2mm	yellow 2-2.5mm	yellow 2mm
Sepals	less than 1mm yellowish green hairy at tips	1mm brownish yellow, hairy at tips	1 or less than 1mm. Yellow with black tints at their tips. densely hairy at tips	1mm white to yellow	less than 1.5mm yellow-brown	1mm yellow
Pods colour when dry	light green to yellow slightly constricted between seeds	light brown not constricted between seeds	yellowish dark brown, less constricted between seeds	yellowish brown not constricted between seeds	light brown slightly constricted between seeds	light brown less constricted between seeds
Indumentum	shortly pubescent with papillate hairs.	pubescent Hairs papillate and curved	very densely pubescent. Long Hairs not papillate Silvery appearance	glabrous to shortly and sparsely pubscent hairs papillate	glabrous	glabrous to shortly and sparsely pubescent hairs papillate and curved
Shape in cross section	round or 8 shaped	straight, curved or e shaped	round &r. e shaped	coiled in a helix or spring	9 or e shaped	loosely coiled
Pod surface	slightly ridged	slightly ridged	ridged	very much ridged with glabular structures	rough and slightly ridged	ridged
Length	7-10(15)cms	5-6cms.	7-10(16)cms	7.5-12cms	7.5-12cms	7-8.5cms
Width	2-4mm	6-12mm	4-6mm	6-7mm	4-6mm	4-5mm
Seeds colour	light to dark brown	dark greenish black	pale green/ black	dark green	green yellow	dark green
length	4-6.5mm	5-7.5mm	5-8mm	5-7mm	4-7mm	5-6mm
width	4-5mm	3-5.5mm	3-6mm	3-6mm	4.5mm	2-4mm
shape	crescent	crescent	crescent	crescent	crescent	crescent
Areole colour	pale yellow	yellow green	green brown	green brown	pale green	green
length	4mm	3-4mm	2-4mm	3-4mm	3-5mm	3-5mm
width	2.5mm	2-3mm	2-4mm	2-4mm	3-4mm	1-3mm
Glands	rare or none on petiole and pod. (A crescent shaped on petiole)	green to brown on petioles. red and black on pods all not constant (look like round discs on petiole)	green to brown in colour on petiole. red glands on pods. all not frequent	on petiole brown in colour not constant. (oval to oblong in shape)	no glands on petiole or pods	no glands on petiole or pods
involucel position from base of peduncle	below or near the middle of the peduncle from base	one third of the peduncle from base	one quarter of the peduncle from the base	one third of the peduncle from base.	below or near the middle of the peduncle from base	below or near the middle of the peduncle from base

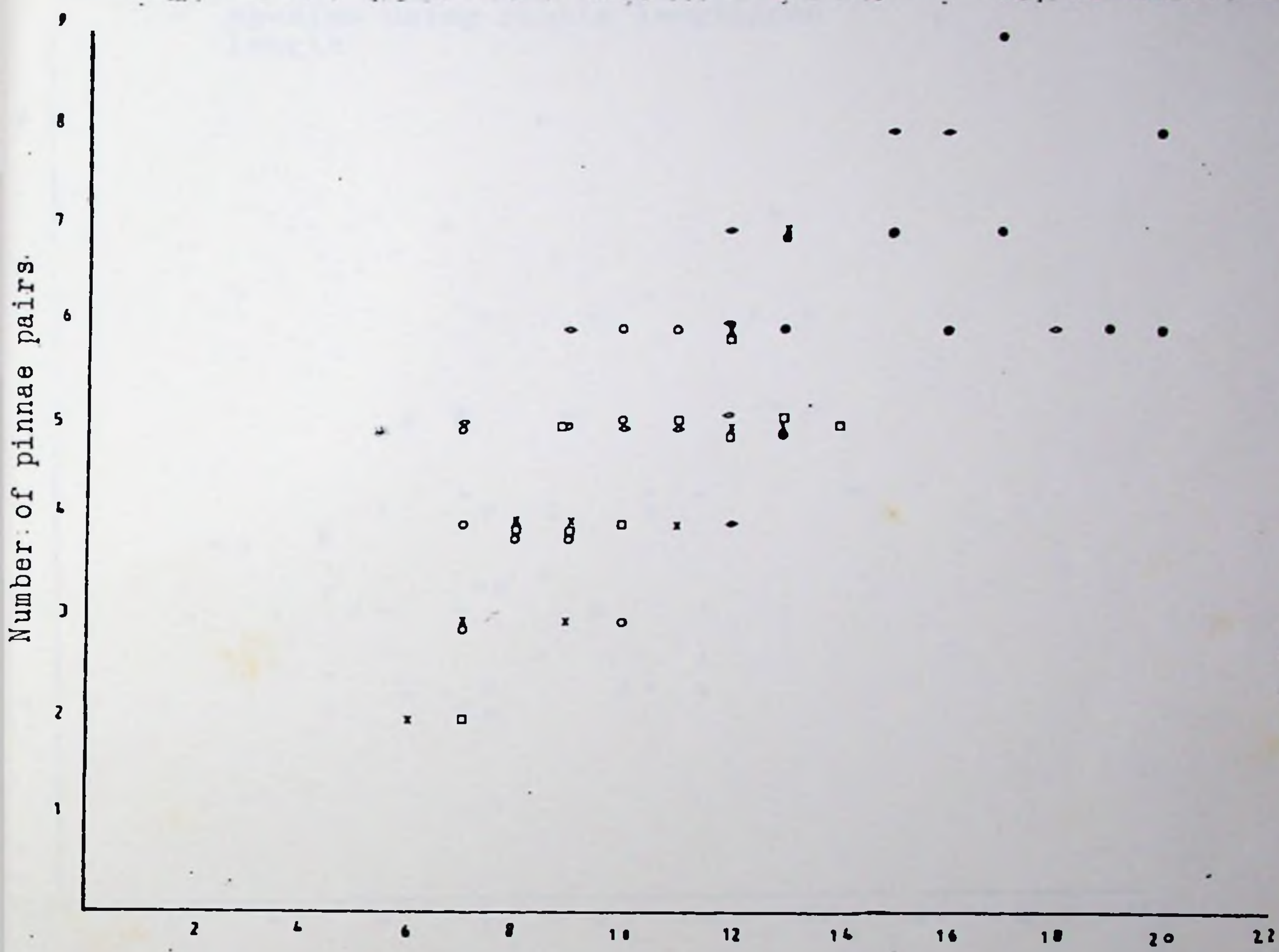
the pollen grains of the subspecies.

2.3 Results

The summary of the morphological characters shows a comparison of characters among the subspecies of Acacia tortilis. Subspecies raddiana is different from the rest of the subspecies by being a tree with a round crown and with a red to brown bark, with red glabrous branchlets, and with glabrous pods. Ssp. raddiana has longer thorns than other subspecies (the slender white long thorns). The leaflets of ssp. raddiana and ssp. tortilis show the same shape. Subspecies spirocarpa var. crinita differs from the rest of the subspecies by having dense long silvery white hairs on the pods and it is not papillate as in other subspecies which have hairs on pods. The peduncle and rachis are also densely pubescent. Subspecies tortilis attains a height from 1-4 meters high, so it is the shortest of all the subspecies and it is usually many stemmed. It has short leaves and leaflets and its pod width is the smallest. There is little difference between ssp. heterecantha and ssp. spirocarpa. Ssp. heterecantha has sparsely pubescent pods and branchlets and has glands on the pods at times.

The Scatter diagrams were drawn to show the position of ssp. raddiana and its relationship with the rest of the subspecies and also to see the position of ssp. spirocarpa with ssp. heterecantha The first scatter diagram shows the relationship of the number of pinnae pairs and number of leaflet pairs in the 4 subspecies.

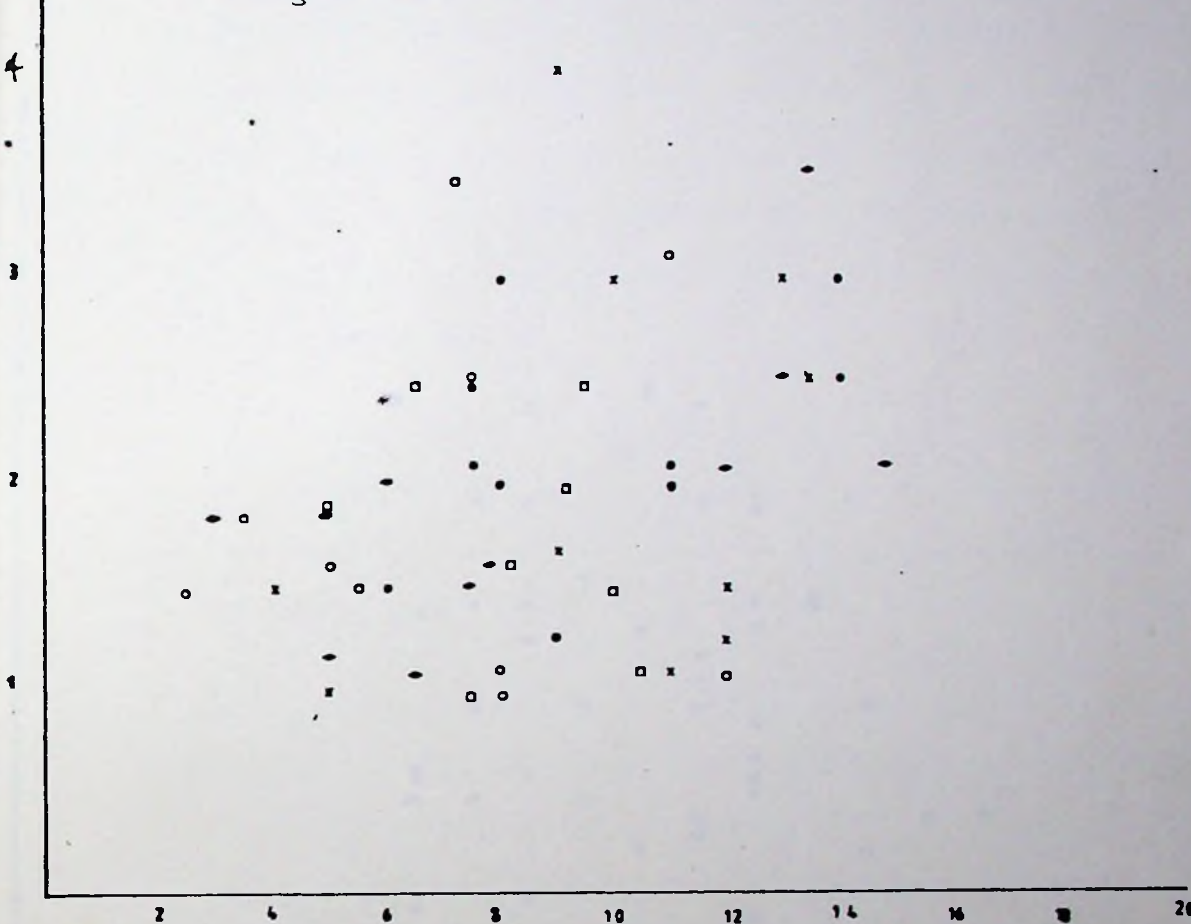
Scatter diagram 1 to show quantitative relationship between subspecies using number of pinnae pairs/leaflet pairs.



- ssp. spirocarpa var. spirocarpa
- ssp. heterecantha
- ssp. tortilis
- ssp. spirocarpa var. crinita
- ssp. raddiana var. raddiana.

3

Scatter diagram 2 to show the quantitative relationship between sub-species using rachis length/pod length



Pod length in centimeters

- ssp. <u>spirocarpa</u> var. <u>spirocarpa</u>

• ssp. <u>heterecantha</u>

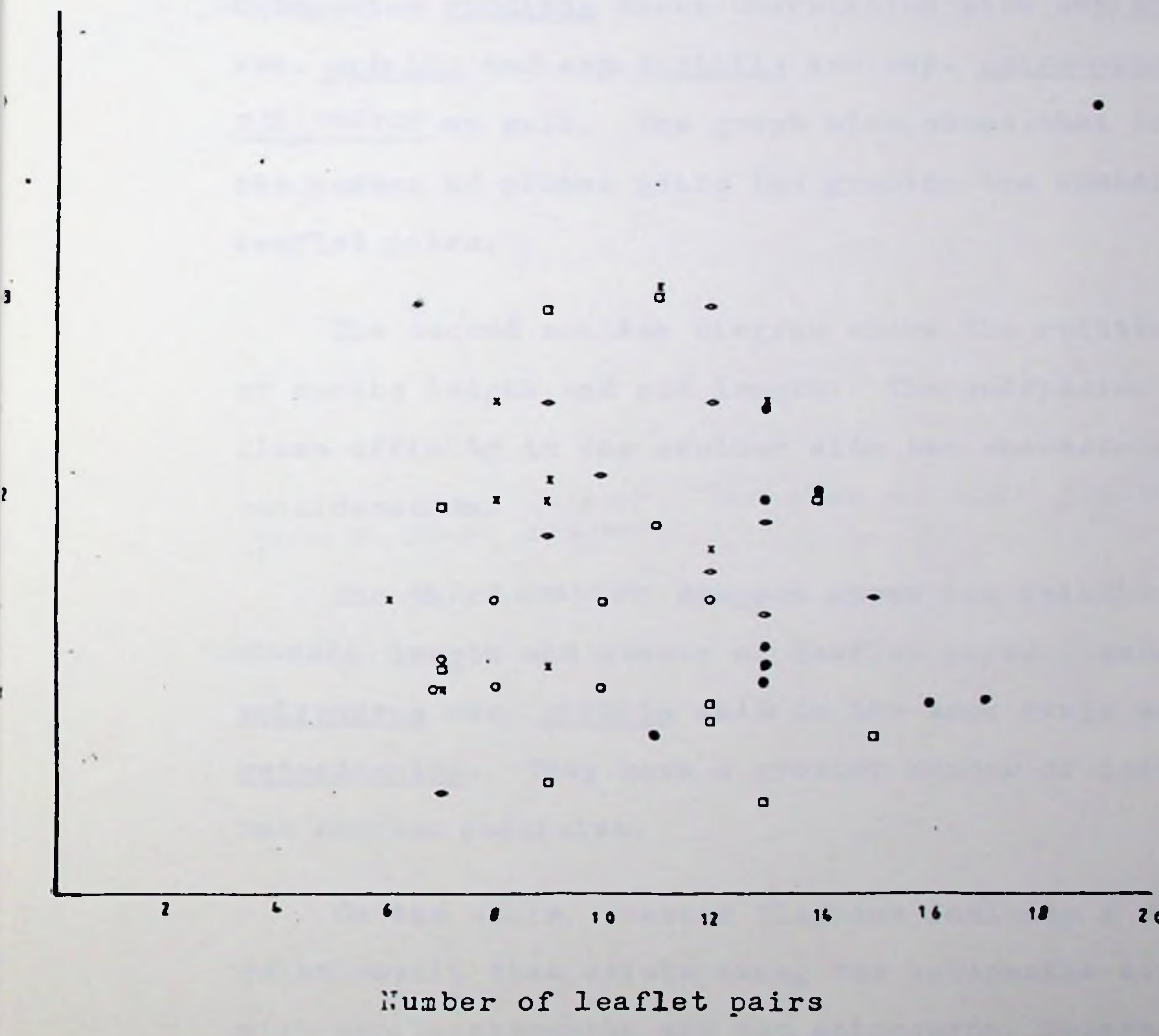
o ssp. <u>tortilis</u>

□ ssp. <u>spirocarpa</u> var. <u>crinita</u>

x ssp. <u>raddiana</u> var. <u>raddiana</u>.

n

Scatter diagram 3 to show the relationship between the subspecies using peduncle/number of leaflet pairs



- ssp. spirocarpa var. spirocarpa
- ssp. heterecantha
- ssp. tortilis
- ssp. spirocarpa var. crinita
- ssp. raddiana var. raddiana.

Acacia tortilis ssp. *raddiana* var. *pubescens* was not included in the graphs, because they were few specimens which were represented. Subspecies *heterecantha* and ssp. *spirocarpa* occur more or less in the same range, and they show the highest number of pinnae pairs and leaflet pairs. Subspecies *raddiana* shows correlation with ssp. *spirocarpa* var. *crinita* and ssp. *tortilis* and ssp. *spirocarpa* var. *spirocarpa* as well. The graph also shows that the higher the number of pinnae pairs the greater the number of leaflet pairs.

Is it positive or negative?

The second scatter diagram shows the relationship of rachis length and pod length. The subspecies shows close affinity to one another with the characters under consideration. Infact This looks the most logical Conclusion from the scatter diagrams

The third scatter diagram shows the relationship of peduncle length and number of leaflet pairs., subspecies *spirocarpa* var. *crinita* falls in the same range with ssp. *heterecantha*. They have a greater number of leaflets but shorter peduncles.

On the whole, scatter diagrams indicate a close relationship that exists among the subspecies especially with ssp. *heterecantha* and ssp. *spirocarpa*. Subspecies *heterecantha* is associated with either ssp. *spirocarpa* var. *spirocarpa* or ssp. *spirocarpa* var. *crinita* in the 3 graphs.

(1) In fact none of the scatter diagram shows an significant correlation among the species. Two logical conclusions can be drawn:-
(a) The subspecies are actually one species
(b) The characters used in the separation of the subspecies are not suitable. Other characters should be investigated

(2) In 1st paragraph you say there was a correlation, ~~was~~ did you go ahead to carry out statistical tests to see if it was significant?

CHAPTER 3

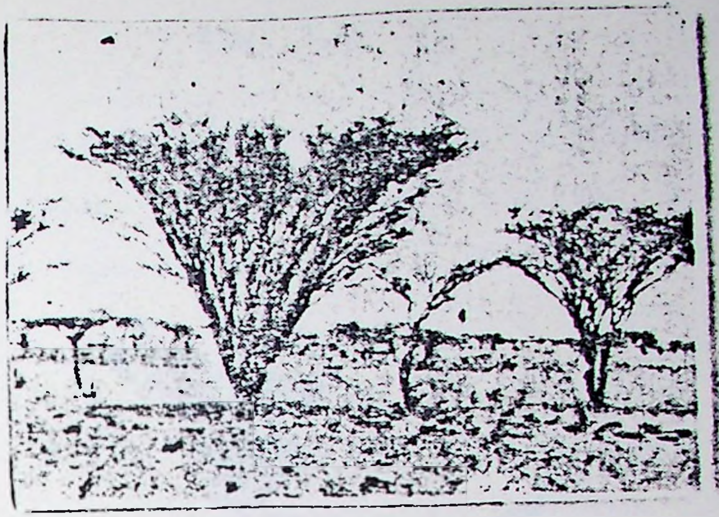
MORPHOLOGICAL DESCRIPTION

Vegetative morphology

3.1 Habit

All the subspecies of Acacia tortilis are woody and they grow as shrubs, bushy shrubs or trees. The size can vary but climate and habitat seem to play part in the range of variation in size and habit (Timberlake 1980, Carr, 1976). Figure 3:1 shows ssp. spirocarpa from two different regions. The one from the Sudan is a shrub and the one from Tanzania is a tree. However, on many occasions, the shrubby forms of Acacia tortilis produce big divided stems forming big shrubs with spreading crowns. These shrubs can easily be mistaken by some workers, to be trees when they are still shrubs. Subspecies raddiana has been noted on many occasions to be a short tree with a round crown (Elamin 1973, Karschon 1961, Halevy 1972). Ssp. heterecantha is a shrub in warmer areas otherwise it is a tree (Carr 1976). Ssp. tortilis is a shrub and ssp. spirocarpa can be both a tree and a shrub depending on climate as well. In higher altitudes it is a tree yet in lower altitudes it is a shrub. The issue of habit in Acacia tortilis can cause disagreements especially in case of workers who stay in the regions where Acacia tortilis is found. However, all the subspecies have flat spreading crowns except subspecies raddiana. The height varies from one metre to eighteen metres high.

Fig. 3.1



3.1 (i) Acacia tortilis ssp. spirocarpa from Sudan (Elamin 1973)

3.1(ii) Acacia tortilis ssp.spirocarpa from Tanzania (Lind and Marrison 1974)

Fig. 3.2

Acacia tortilis subsp. heteracantha (Timberlake 1980)

(a) The recurved spine

(b) The long slender spine

(c) The twisted pod

3.2 Stems

The shrubby forms of Acacia tortilis produce more than one stem. It is only ssp. raddiana which has one stem. The texture and colour of the bark does not vary much. The barks have longitudinal fissures and the colour varies from grey to brown black. The colour of the bark is different when a tree is young, mostly greyish-cream but during maturity a dark grey or brown colour is attained. However, Acacia tortilis ssp. raddiana has a light reddish bark when young which continues to darken when it matures. The young branchlets are lenticelled and their colour vary from yellow to red brown.

3.3 Spines

Spines form a diagnostic feature of most African Acacias, however the types of spines found in Acacia tortilis contribute a diagnostic character of this species. There are two kinds of spines found in Acacia tortilis. The long straight white to grey slender forms and the short recurved black and brown forms. The length of the long spines varies from 1.5 - 7 centimeters long. The short ones vary from 1-4 millimeters long. Each form occurs in a pair at a node, each pair having a common base. The members of a pair can be all straight and long, or they can be all recurved, and occasionally a pair of a long straight spine and a short recurved one occurs. The tree or shrub as a whole produces all the two forms of spines. The tips of both forms of spines

overlapping in length

Fig. 3.3

Acacia tortilis ssp. spirocarpa, with

(i) flowers and

(ii) leaves

~~is~~ are usually dark red to brown in colour. The ~~species~~ Spines are arranged spirally along the branchlets. The number of long spines in ssp. tortilis, heterecantha and spirocarpa is small, while the number of short recurved ones is big, which is the opposite for ssp. raddiana. (3.2)

Did you carry out a statistical test for this? A scatter diagram would suffice

a t-test might do.

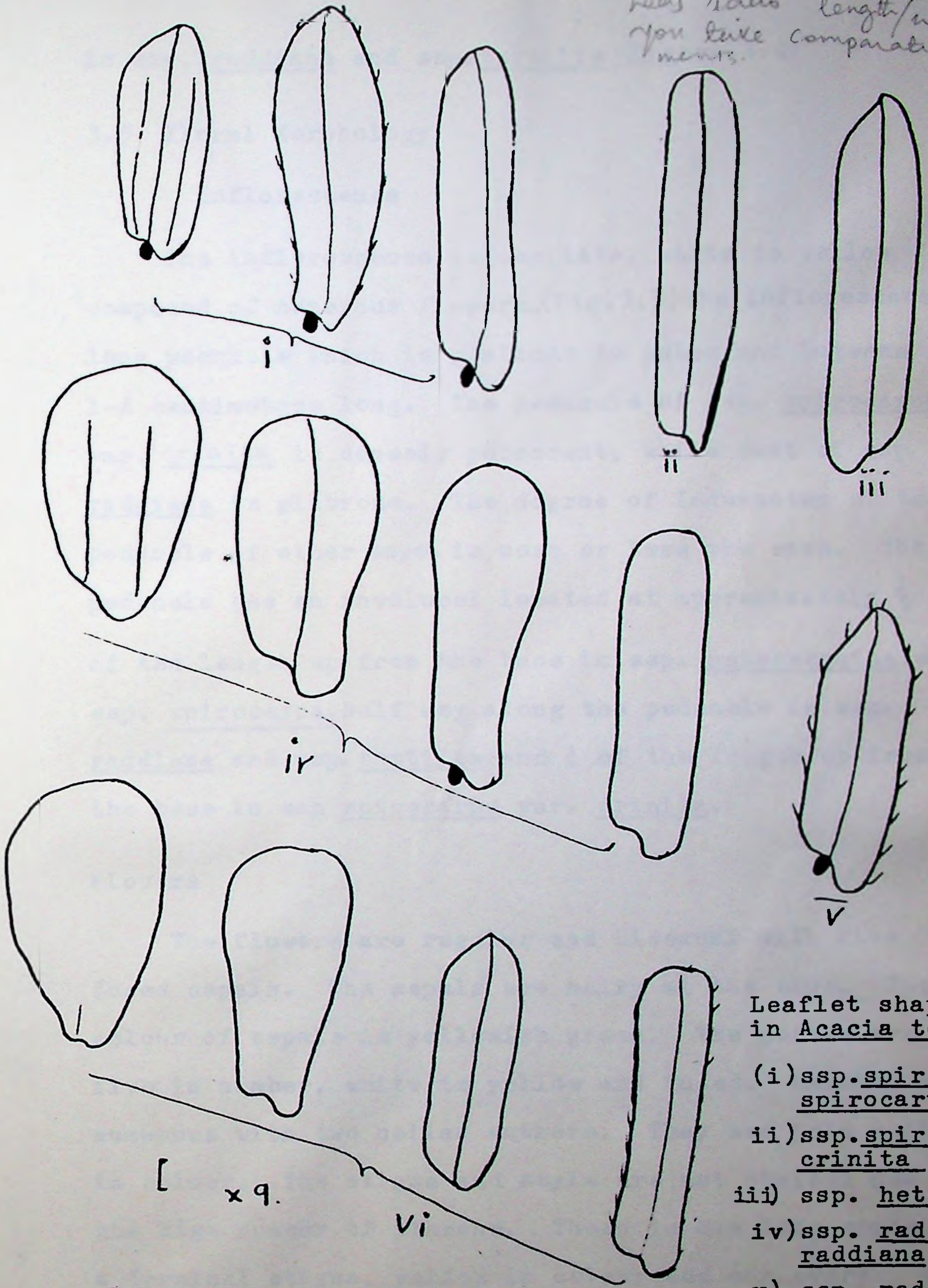
3.4 Leaves

Is this an original observation

The leaves of Acacia tortilis are bipinnately compound and the number of leaves per node vary between 2-6 leaves (Fig 3.3) The petioles are glabrous to pubescent from Imm to 6mm long. The rachis is grooved on top and is glabrous to pubescent. The pinnae are not in precise pairs along the rachis and the longest ones are situated more or less in the middle of the rachis. Pinna pairs vary from 3-10 in number. The leaflets form precise pairs along the rachillae with oblong to obovate shape. The length of the leaflets varies from 1-5mm long and 1-3mm wide. The leaflet pairs are from 7-20 in number. The leaflet midrib cannot be seen clearly, but it can be discerned on the underside of the leaflet. On several occasions, some branchlets get different shapes of leaflets from the normal, with wide rounded tips forming an obovate shape and these leaflets are shorter than the common leaflets. Ross (in 1979), mentioned Acacias that produce primary and secondary leaves. He said that the primary leaves occur singly at the nodes on actively growing branchlets while the secondary leaves are fascicular and arise from dwarf lateral shoots at the nodes. The short obovate leaflets may probably be from the secondary leaves of Acacia tortilis and these were found mainly

Fig. 3.4

1. Is this drawn to scale?
2. If so there seems to be obvious ~~leaf~~ variation in leaf ratio length/width. Did you take comparative measurements.



Leaflet shapes found in Acacia tortilis

(i) ssp. spirocarpa var spirocarpa

ii) ssp. spirocarpa var crinita

iii) ssp. heterecantha

iv) ssp. raddiana var. raddiana

v) ssp. raddiana var. pubescens

vi) ssp. tortilis

in ssp. *raddiana* and ssp. *tortilis* (Figure 3.4)

3.5 Floral Morphology

Inflorescence

1) original observation? The inflorescence is capitate, white to yellow composed of numerous flowers.(Fig.3.3)The inflorescense has a long peduncle which is glabrous to pubescent between 1-4 centimetres long. The peduncle of ssp. *spirocarpa* var. *crinita* is densely pubescent, while that of ssp. *raddiana* is glabrous. The degree of Indumentum of the peduncle of other ssps. is more or less the same. The peduncle has an involucel located at approximately $\frac{1}{3}$ of the length up from the base in ssp. *heterecantha* and ssp. *spirocarpa*, half way along the peduncle in ssp. *raddiana* and ssp. *tortilis* and $\frac{1}{4}$ of the length up from the base in ssp *spirocarpa* var. *crinita*.

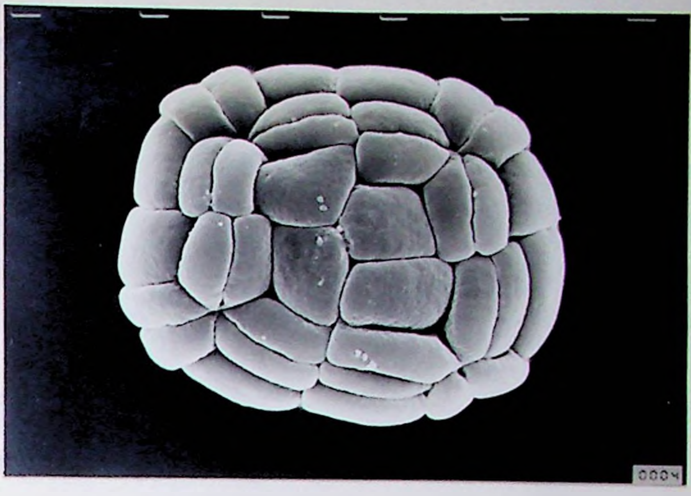
Statistical Analysis?

Flowers

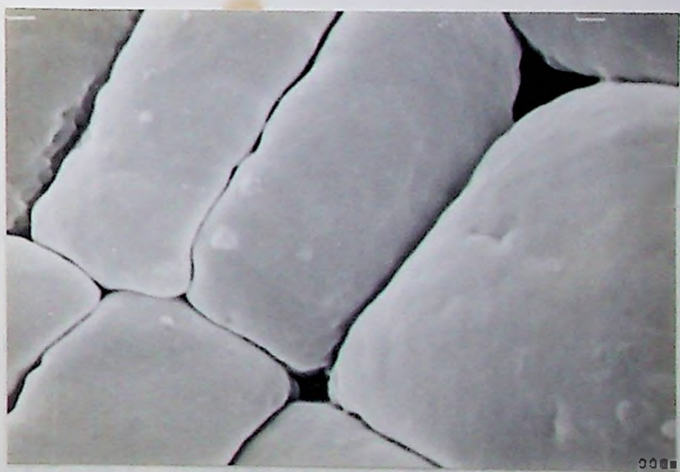
The flowers are regular and bisexual with five fused sepals. The sepals are hairy at the tips. The colour of sepals is yellowish green. The petals are five in number, white to yellow and fused. Stamens are numerous with two celled anthers. They are pale yellow in colour. The stigma and style are not obvious due to the high number of stamens. There is one long style with a terminal stigma, yellow in colour and one ovary. All the parts of the flower fuse to one point inside the base of the calyx forming an acute shaped base outside.
The flower does not vary much among the subspecies.

1) Is this your original observation

Fig. 3.5



i) Pollen grains of ssp. spirocarpa var. crinita.
Mag. X2000



ii) The above pollen grain enlarged to show the surface. Cells look like rectangular blocks
Mag. X10,000

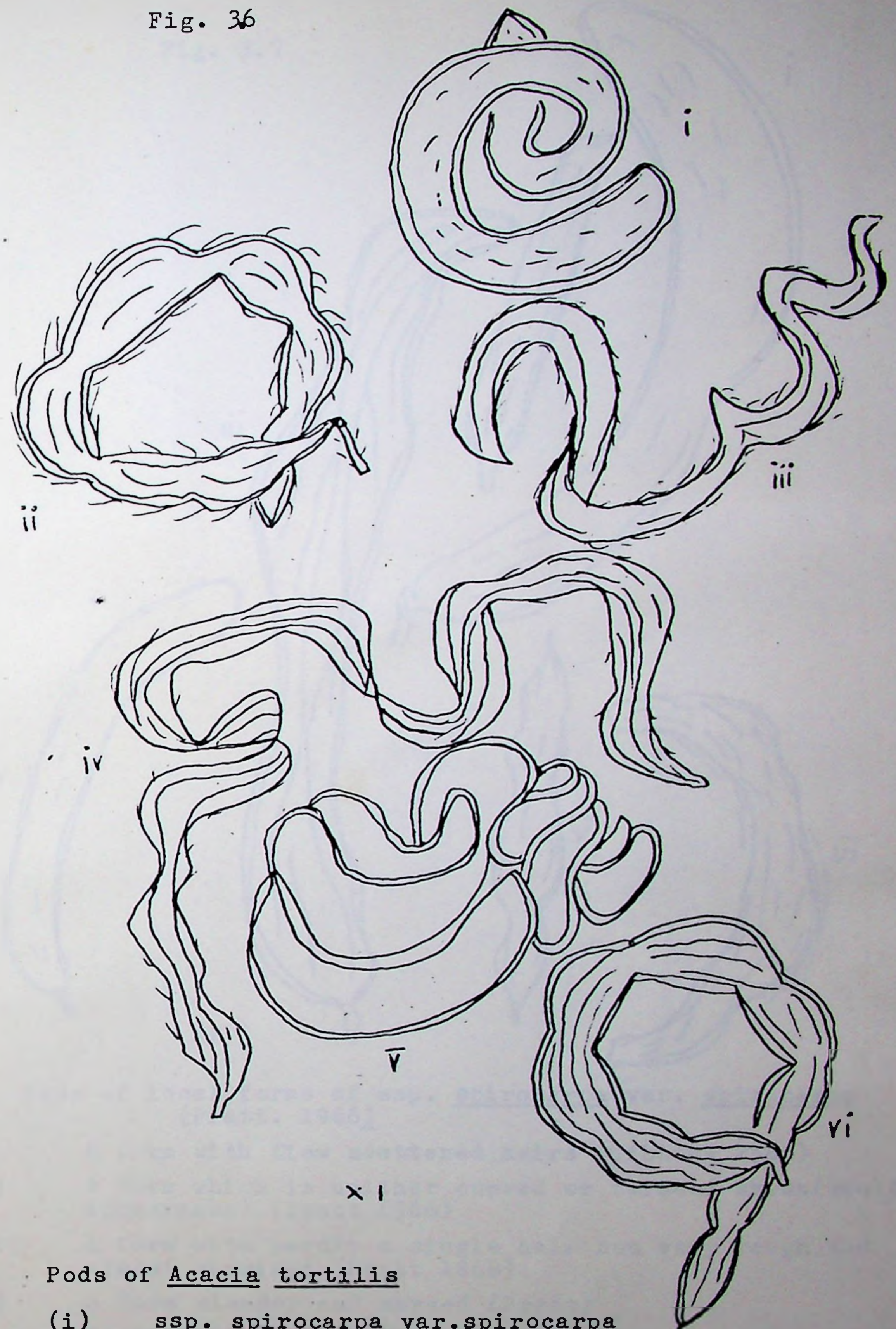
3.6 Pollen

The pollen grains of *Acacia tortilis* occur in aggreggates (polyads.). Individual grains of the group are arranged regularly forming a circular polyad. The grains look like rectangular blocks in a mass.(Fig. 3.5)

3.7 The Pods

Pods form one of the features on which the separation of the subspecies is based and the specific epithet of the name *Acacia tortilis* is due to the twisted morphology of the pod, and hence a diagnostic character for the species. (Quote) The texture of the pod varies from glabrous to densely pubescent. The width varies from 2mm to 12mm wide. The length does not vary. Subspecies *spirocarpa* has the largest pods in width yet its pods are less twisted than the rest. It has local forms in Kenya and Tanzania which are small and slender in width and not coiled, while there are those which have a rough warty surface (Fig. 3.7 and 3.8). On the other hand ssp. *heterecantha* has pods which are more twisted than the rest. The colour of pods is yellow to brown and pods are longitudinally and slightly ridged. Pods contain up to 14 seeds, some of which do not mature. The pods are slightly constricted between seeds except the mature pods of ssp. *tortilis* and ssp. *raddiana* show obvious construction between seeds. Figure 3.6 shows the pods of the different subspecies. The hairs on the surface of pods show some variation. Subspecies *spirocarpa* var. *crinita* has long straight and slightly

Fig. 36



Pods of Acacia tortilis

(i) ssp. spirocarpa var.spirocarpa (Jackson 4246)

(ii) ssp. spirocarpa var. crinita (Milne-Redhead and Taylor 11224)

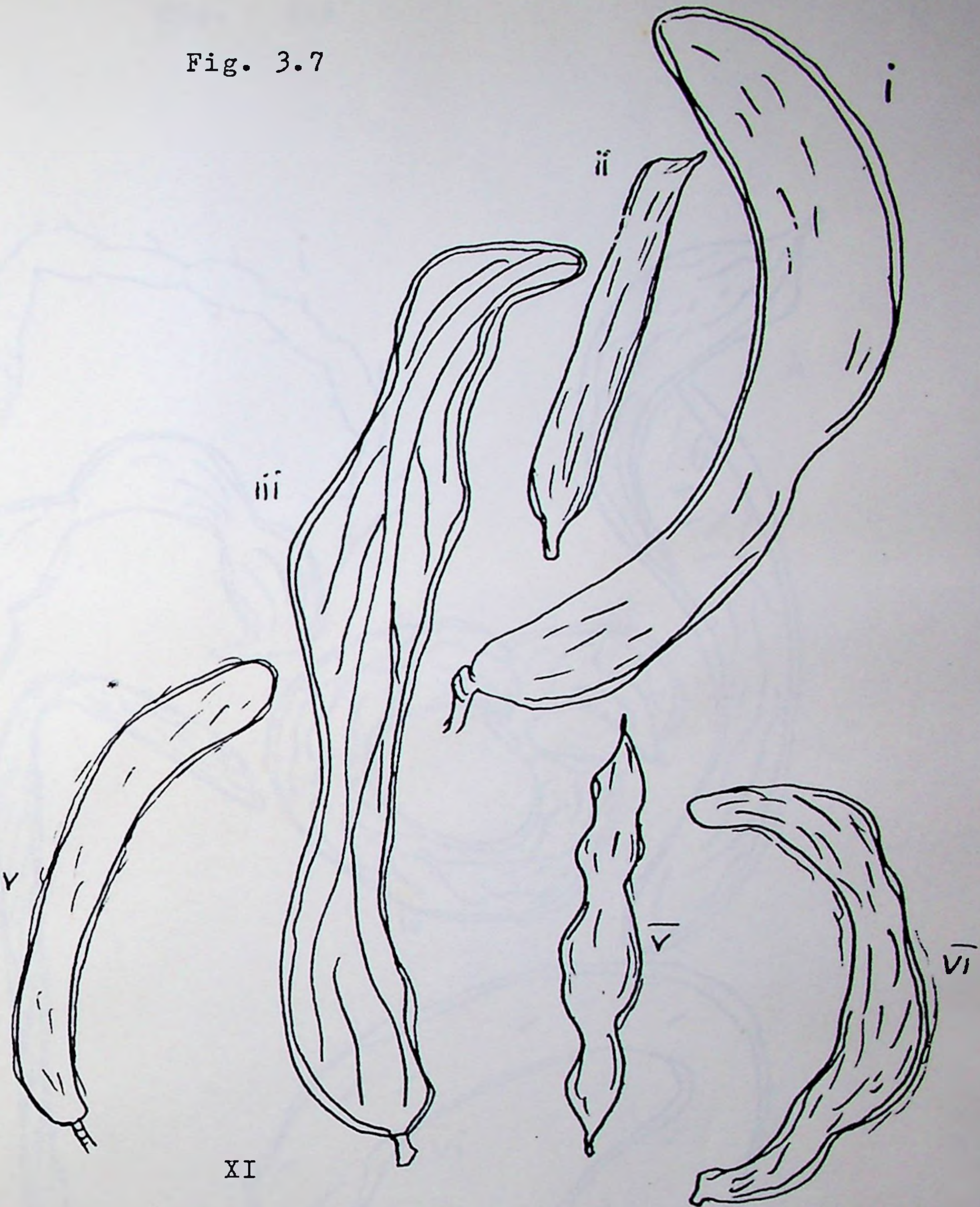
(iii) ssp. tortilis (Pratt 75)

(iv) ssp. raddiana var. pubescens

v) ssp.heterecantha (Drummand 7236)

vi) ssp raddiana var. raddiana

Fig. 3.7



XI

Pods of local forms of ssp. spirocarpa var. spirocarpa (Pratt. 1966)

(i) A form with fiew scattered hairs (Gibbons 2585)

(ii) A form which is neither curved or twisted shows(woolen appearance) (Pratt 1966)

(iii) A form with hardly a single hair but very rough and almost straingt (Pratt 1866)

(iv) A form slender and curved (Pratt)

(v) A straight form which is slightly constricted

(vi) Densely pubescent, curved, hairs short

Fig. 3.8

Variation in pods of Acacia tortilis(diverge from from normal forms)

(i) ssp.spirocarpa var.crinitala pod with few scatter scattered long silvery hairs (Peter 42674)

(ii) and (iv) ssp. spirocarpa var. spirocarpa;type of pods with rough warty surfaces.(Mooney 8254)

(iii) ssp. raddiana var. raddiana; a very short and smooth pod, green in colour (Gillet 23023)

(v) ssp. spirocarpa var. spirocarpa,a pod very heavil (Newbould 5817)

(vi) ssp. spirocarpa var spirocarpa

Single hair of pod ssp. heterecantha
Mag. X1000

1

Surface of a pod ssp.
heterecantha
Mag. X150

Surface of a pod ssp.
heterecantha
Mag. X2000

3

2

Surface view of pod. ssp
spirocarpa. var. crinita
Mag. X500

Surface view of pod. ssp.
spirocarpa var. spirocarpa
Mag. X350

Fig. 3.10

Surface view of a single hair from pod surface of ssp. raddiana var. pubescens
Mag. X1,500

4

Surface view of pod of ssp. raddiana var. raddiana

Mag. X350

5

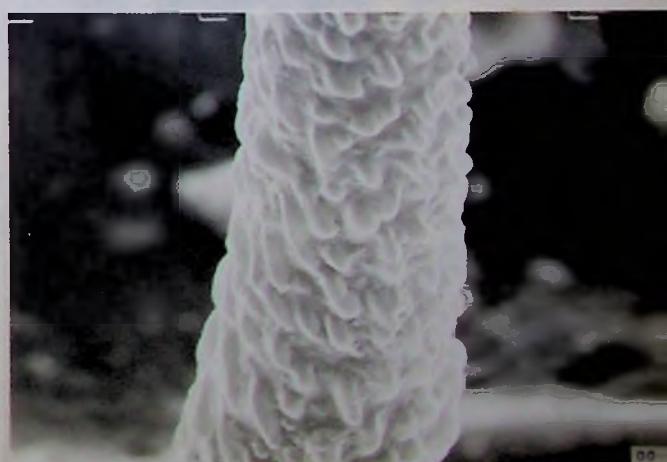
surface view of pod ssp. raddiana var. pubescens

X500

6

Surface view of pod ssp. tortilis .

Mag. X1500



Surface view of single hair from pod of ssp. tortilis

X3,500

Fig. 3.11

Inside surface of the pod when inner membrane is removed.ssp. raddiana var raddiana.
Mag. 1,000

Inside surface of pod when membrane is removed ssp. heterecantha.
Mag. X500

smooth hairs while the rest of the subspecies besides ssp. raddiana var. raddiana, have short papillate hairs. The hairs of ssp. raddiana var. pubescens and that of ssp. spirocarpa var. spirocarpa is curved (Figure 3.9 & 3.10) The surface of pods of ssp. heterecantha shows micro ridges on the pods and it also has globular structures. The inside surface of the pod when the membrane is removed shows variation in ssp. heterecantha (Figure 3.11) Occasionally local forms of the different subspecies occur in some areas, with variation in pod size and degree of indumentum. Subspecies raddiana var. raddiana has some forms with very short pods (J.B Gillet 1980) ssp. spirocarpa var. crinita has forms of pods with few scattered long silvery hairs (Peter 42674) and those with heavily dense silvery hairs (Newbould 5817, 1961) (Figure 3.10)

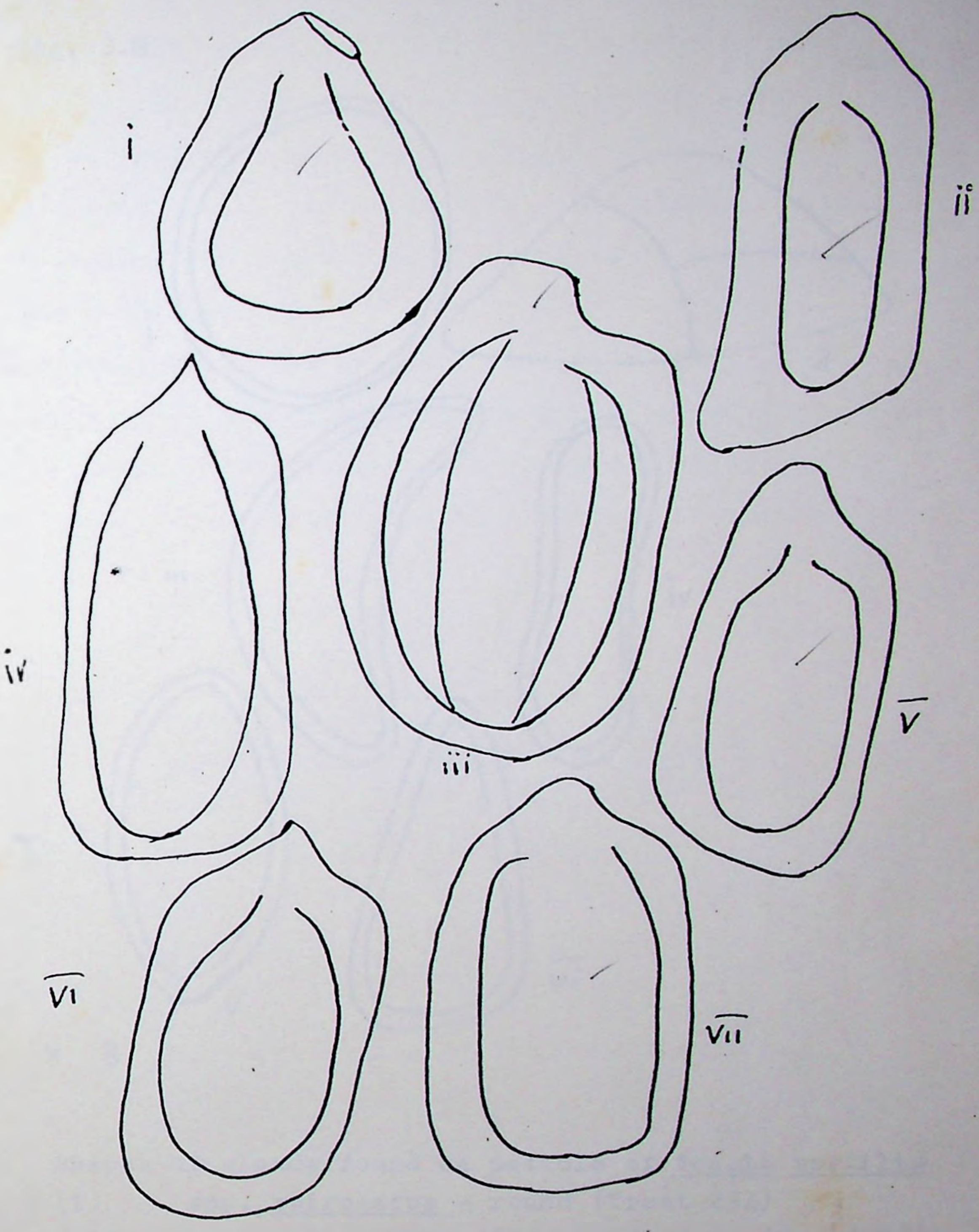
3.8 The Seeds

The seeds are oblong to pear shaped and they are smooth and compressed with a crescent shaped areole. The face dimensions are 6-8mm long and 4-6mm wide. Subspecies spirocarpa var. spirocarpa has bigger seeds. The colour of seeds is from dirty pale green to dark greenish brown. The margins of the areole vary in colour from cream to pale green (Figure 3.12)

3.9 Glands

There is a conspicous gland on the upper surface

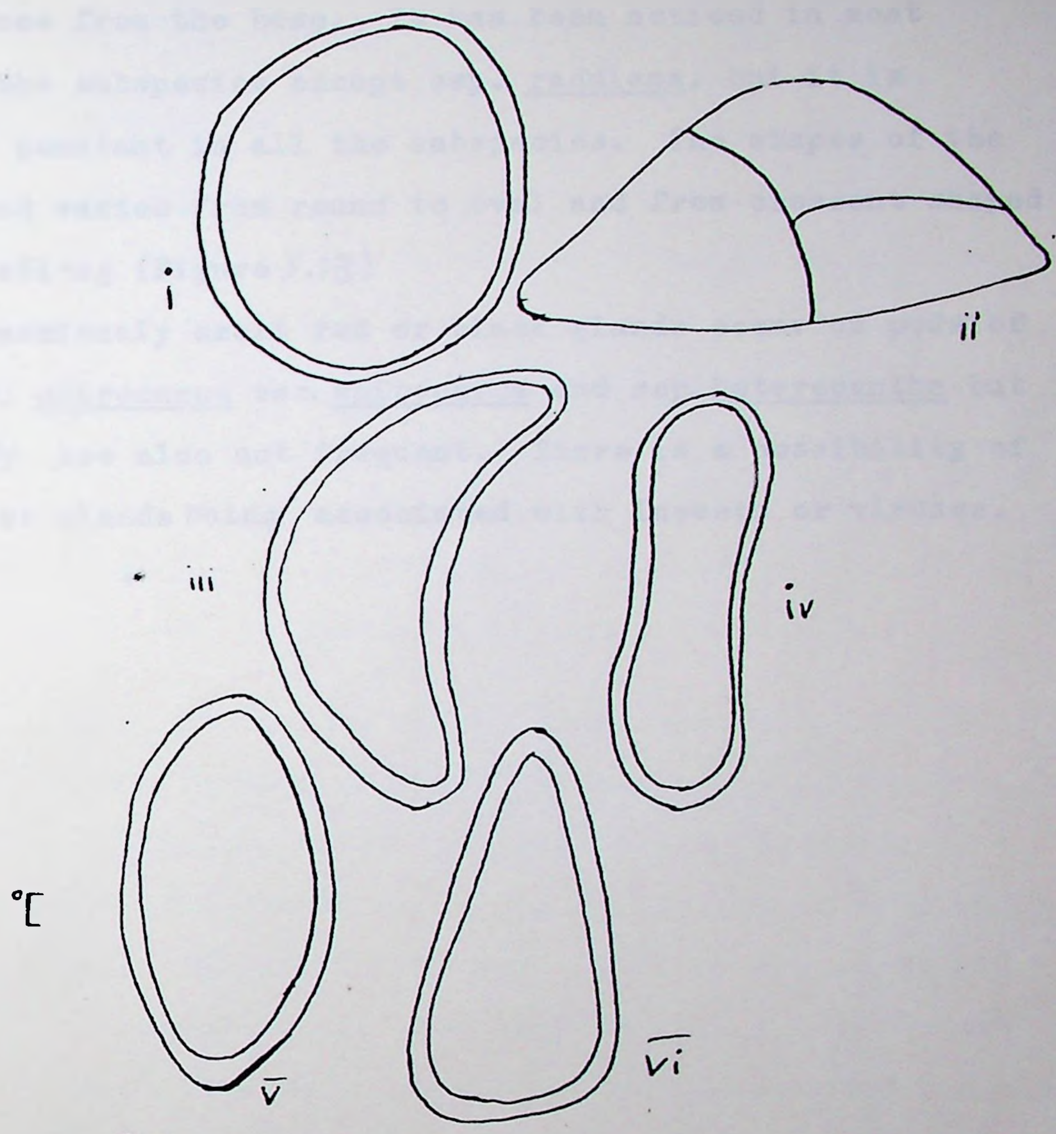
Fig.3.12
The seeds of Acacia tortilis



x 8

i.ss ssp. spirocarpa var. spirocarpa (Semsei 3963)
ii. ssp. tortilis (Pratt 75)
iii. ssp. spirocarpa var. spirocarpa
iv. ssp. raddiana var. raddiana (Walsingham 37)
v ssp. spirocarpa var. crinita (Wood 3090)
vi. ssp. raddiana var. pubescens
vii. ssp. heterecantha

Fig. 3.B



× 8

Shapes of glands found on petiole of <u>Acacia</u> <u>tortilis</u>

(i) ssp. <u>spirocarpa</u> - round (Trott 234)
(ii) ssp. <u>spirocarpa</u> - (i) upside down (Trott 234)
(iii) ssp. <u>tortilis</u> - crescent shaped(Alemayehu Haile)
(iv) ssp. <u>heterecantha</u> - oblong
(v) ssp. <u>heterecantha</u> - oval (Hanekam 2528)
(iv) ssp. <u>heterecantha</u> - pear shaped (Ross 3017)

of the petiole of the leaf before the first pair of pinnae from the base. It has been noticed in most of the subspecies except ssp. raddiana, but it is not constant in all the subspecies. The shapes of the gland varies from round to oval and from crescent shaped to oblong (Figure 3.13)

Occassionaly small red or black glands occur on pods of ssp. spirocarpa var. spirocarpa and ssp. heterecantha but they are also not frequent. There is a possibility of these glands being associated with insects or viruses.

CHAPTER 4

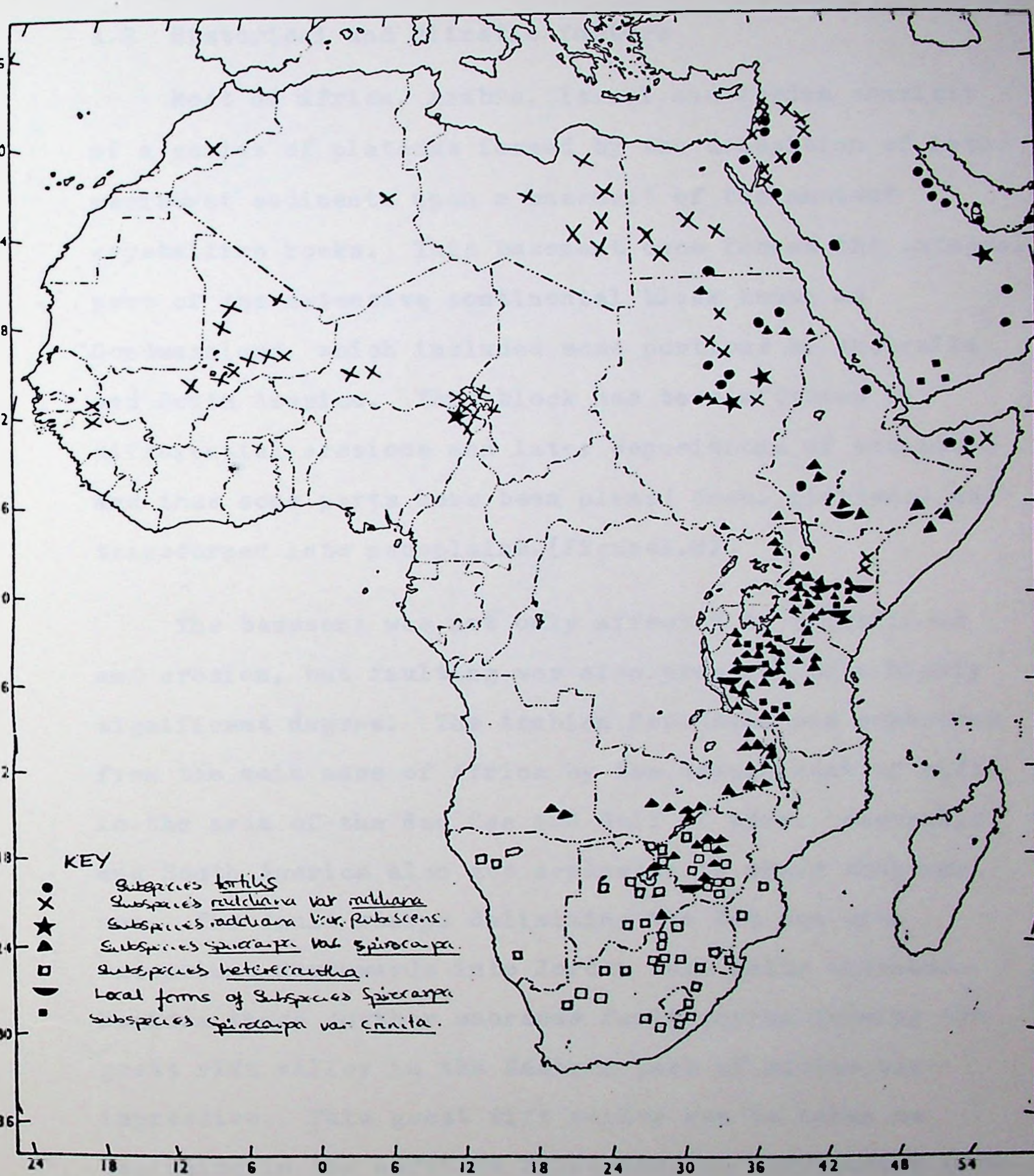
THE DISTRIBUTION OF *Acacia tortilis*

4.1 Introduction

Acacia tortilis is widely distributed in Africa from the south of the Continent to the North and then in to some parts of the Middle East namely Arabia, Jordan and Israel. The distribution map has been prepared on the basis of the information from the plant specimens which were under study, and also with the aid of catalogues for grid references, to locate the different places where the species is found (Figure4.1).

The distribution of any plant can be accounted for by various factors of which climate plays an important role. It is suggested that the Eastern Sudan or some parts of adjacent Ethiopia may be the centre of dispersal of *Acacia tortilis* (Burtt-Davy 1930; Zohary 1962) and if this suggestion is true then several other factors besides climate have to come in, to account for the way *Acacia tortilis* spread from the Sudan to the South of Africa, to the West, to the north and north East of the Continet. During the spreading of *Acacia tortilis* some areas were jumped by the species to occupy those beyond, yet some areas have few of the species than others. Historical and ecological elements, human and animal activities and climate in addition all have played part in the distribution pattern of *Acacia tortilis*. A brief overview of the climatic patterns and topography of Africa, Arabia Israel and Jordan would serve as an essential background

Fig. 4.1 The distribution of Acacia tortilis



to account for the distribution of Acacia tortilis.

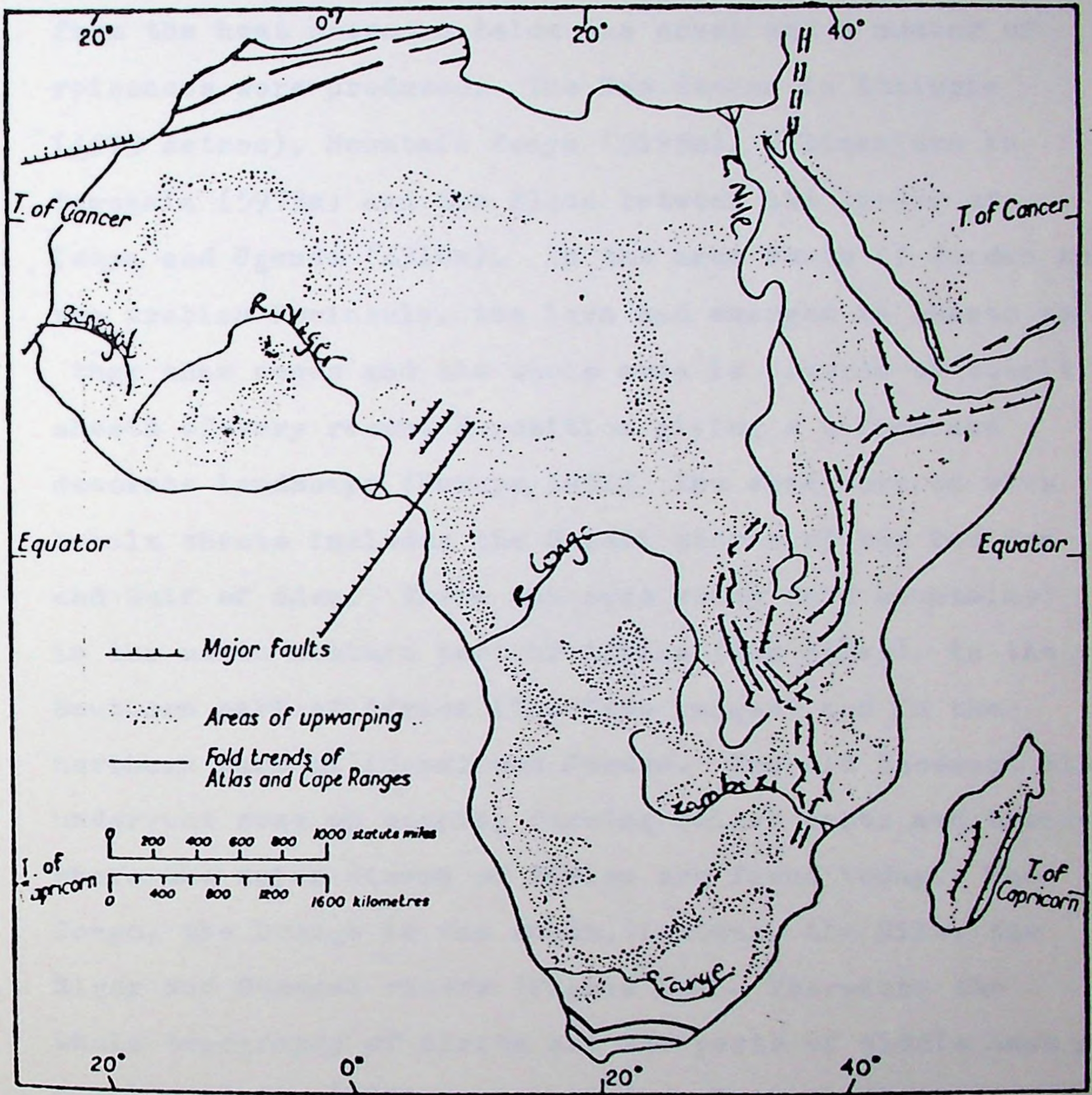
4.2 Historical and climatic factors

Most of Africa, Arabia, Israel and Jordan consists of a series of plateaus formed by the deposition of later resistant sediments upon a basement of the ancient crystalline rocks. This basement once formed the integral part of the extensive continental block known as Gondwanaland which included some portions of Australia and South America. This block has been affected by differential erosions and later depositions of sediments and thus some parts have been planed down, flattened and transformed into peneplains.(Figure4.2).

The basement was not only affected by depositions and erosion, but faulting was also present, to a highly significant degree. The Arabian Peninsula was separated from the main mass of Africa by the development of rifts in the area of the Red Sea and Gulf of Aden. Australia and South America also got separated to where they are now. The fault scarps delimiting the Red Sea with extensions northwards into Jordan were quite enormous. Besides these further enormous fault scarps forming the great rift valley in the Eastern part of Africa was impressive. This great rift valley can be taken as beginning in the northern Syria thus in association with Jordan, Red Sea rift valley and the trough of the Red Sea may be considered to form the connecting link between

Fig. 4.2

The rift valley system and the upwarping in Africa and the Middle East (Harrison Church 1965)



the northern rift valley and that of Eastern Africa. Figure 4.2 shows the extension of the rift valley system. Associated with faults was the production of lava flow from the heat pressure below the crust and a number of volcanoes were produced. The Ras. dashan in Ethiopia (4573 metres), Mountain Kenya (5195m), Kilimanjaro in Tanzania (5973m) and the Elgon between the border of Kenya and Uganda (4310m). In the area South of Jordan and the Arabian Peninsula, the lava had emerged in sheets rather than cones and the whole area is covered by basalt sheets of very recent deposition giving a barren and desolate landscape (Europa, 1961) The area covered with basalt sheets includes the Somali shores of the Red Sea and Gulf of Aden. There are some young fold mountains in the north western part of Africa (The Atlas), in the Southern part of Africa (The Cape ranges) and in the northern part of Israel and Jordan. The old basement also underwent some up warping forming raised parts and basins where the major rivers of Africa are found today. The Congo, the Orange in the south, Zambezi, the Nile, the Niger and Senegal rivers (Figure 4.2). Therefore the whole topography of Africa and the parts of Middle East under consideration forms a series of plateaus, basins, plains and fold mountains.

Most rivers in Israel, Jordan and Arabia are seasonal rivers, formed during the rainy season. The water flows in rocks and percolates there. Many seasonal rivers dry up leaving dry beds known as Wadis. These are very common in Arabia and Israel and they have played part in maintaining some species of Acacia tortilis in deserts.

Africa lies astride the equator, and this gives the continent the maximum expression of tropical conditons, for about 90 percent may be classified as tropical, the highest percentage for any Continent (Hance, 1964). The equatorial position also means that the temperatures are high over the bulk of the continent. Therefore it follows that the element of climate which is of most significance is precipitation (Figure 4.3). On a continental basis, Africa leads the world in the extent of dry climates, possessing about a third of the world and having the highest percentage of arid lands of any continent except Australia (Figure 4.4). Monthly mean temperatures below 40°F are found in the fold mountains in the North Western part of Africa during January and along the escarpment of South Africa in July, while close to the Equator several East African peaks are high enough to nourish snowfields and glaciers. In January, only the area north of Cancer is below 60°F, and south of this most of Africa has average temperatures between 70°F and 80°F. In july the average temperature is over 80°F almost everywhere north of 12° North and many areas exceed 90°F. The annual movement of the sun back and forth between the tropics is usually followed by a belt of low pressure and a high pressure north and south of the belt causing winds to

Fig. 4.3

Average Annual Precipitation in Africa and the Middle East (Hance 1964)

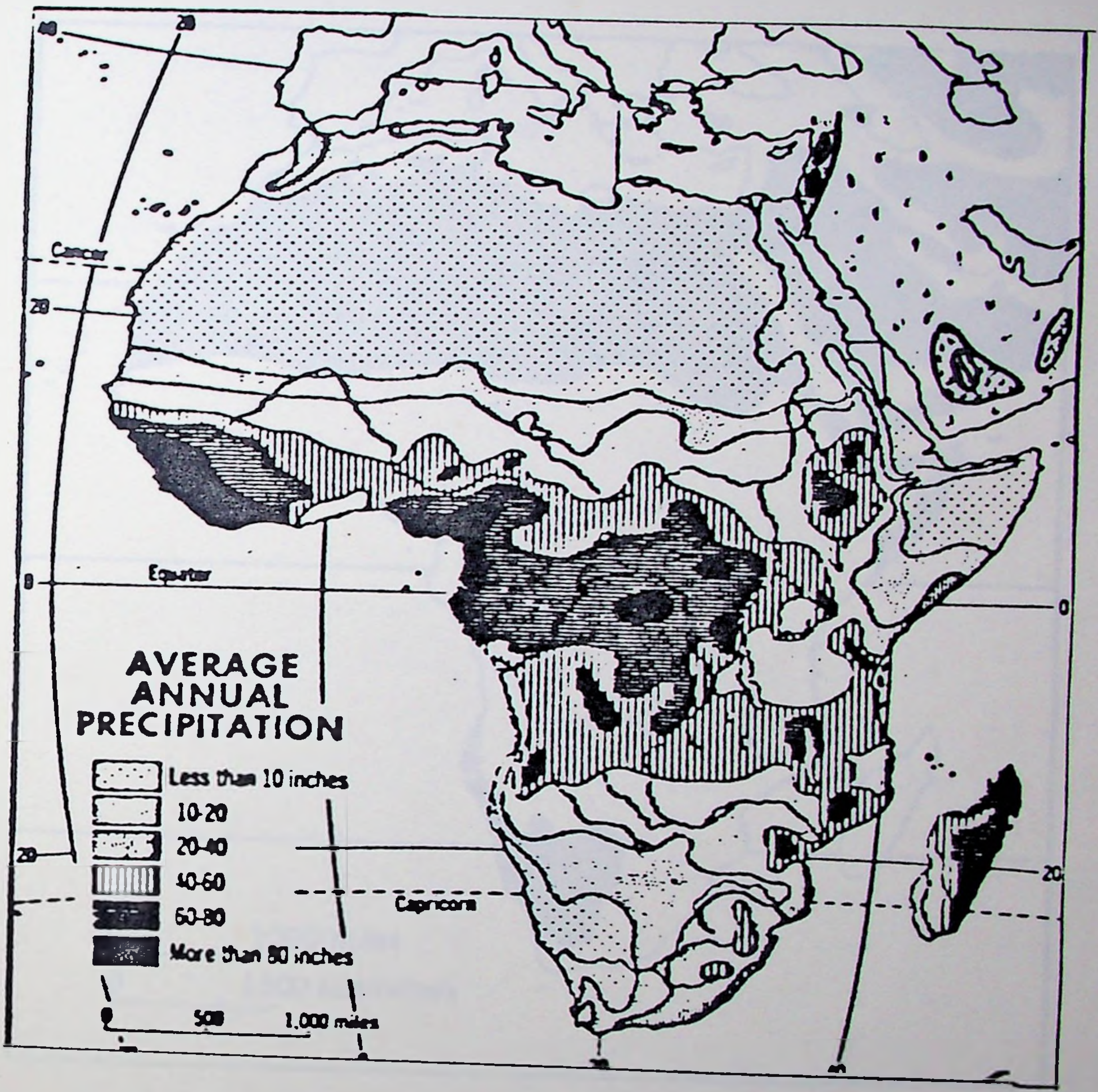
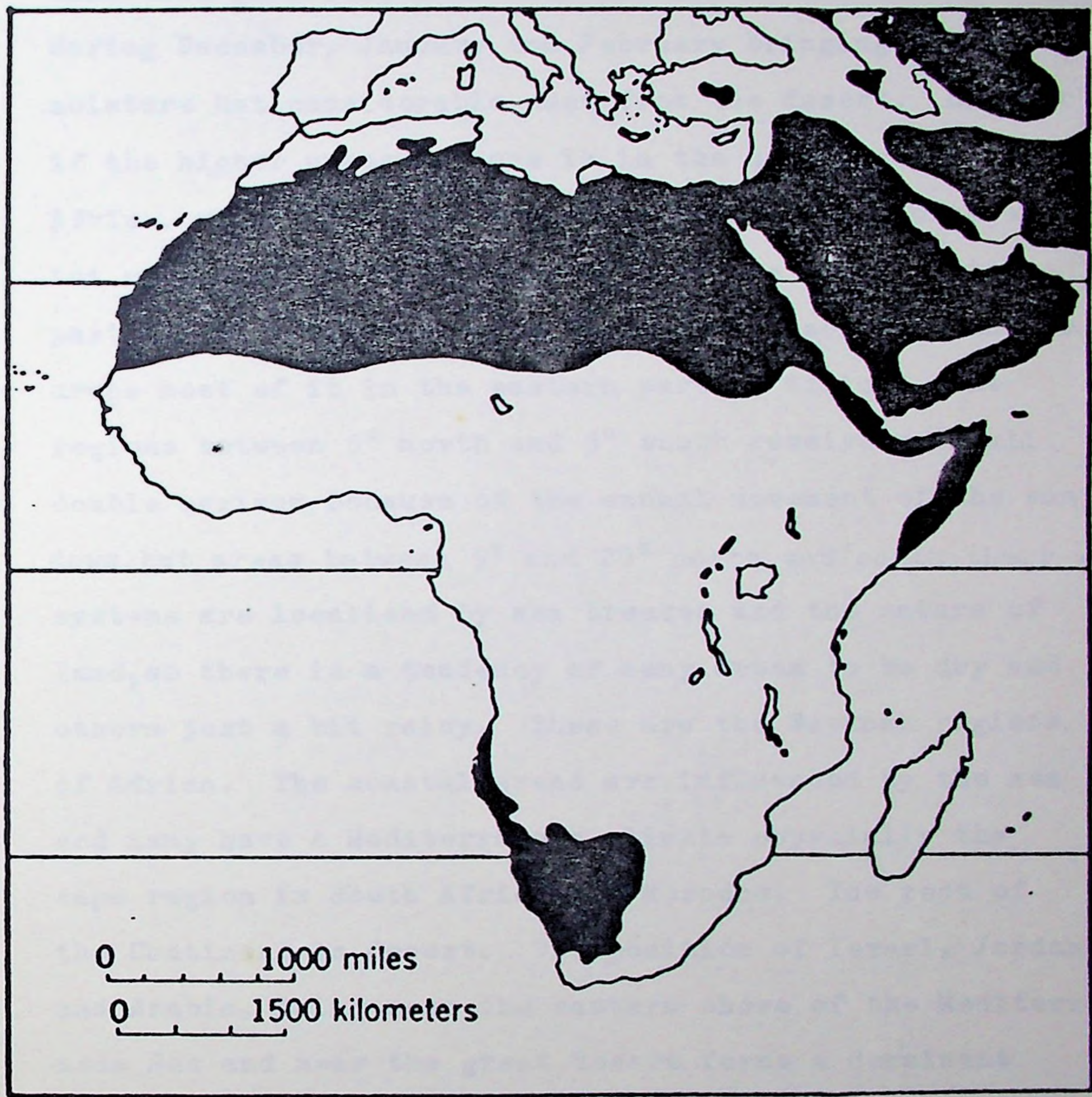


Fig. 4.4

The Arid Lands of Africa and the Middle East (in black) (Dudley Stamp 1952)



blow in it on either side bringing rain and thunderstorms. From the higher pressure zone which develops over the Sahara, wind will generally blow from the north-east to the south east during December, January and February bringing little moisture but considerable dust from the desert. However if the higher pressure zone is in the southern part of Africa, winds blow from the south west to the north east but much more to the east because of the bulky western part of the continent. The wind carries moisture and ~~dr~~ drops most of it in the eastern part of Africa. The regions between 5° north and 5° south receive rainfall double maximum because of the annual movement of the sun up and down, but areas between 5° and 20° north and south their wind systems are localised by sea breezes and the nature of land, so there is a tendency of many areas to be dry and others just a bit rainy. These are the Savanah regions of Africa. The coastal areas are influenced by the sea and many have a Mediterranean climate especially the cape region in South Africa and Morocco. The rest of the Continent is desert. The position of Israel, Jordan, and Arabia, being near the eastern shore of the Mediterranean Sea and near the great desert forms a dorminant feature of their climatic character; it is a zone of transition between the Mediterranean and desert climates. The climate is of a relatively long hot summers and a mildy winter with short intermediate periods of autumn which is warm and sunny and a changeable spring. The fact that there are no clouds in the sky always, temperatures can go up to 115°F especially in some parts of

Arabia. Rainfall is very scanty with less than 254mm. In areas where rainfall exceeds 762mm (30 inches), these are upland areas close to the big sea like northern Israel and Jordan (Fig 4.3)

How then can these factors account for the distribution of Acacia tortilis: Before the break up of Gondwanaland, Israel, Jordan and Arabia were closely linked with Africa and they were still governed by the tropical type of climate. The present Mediterranean countries were also under similar climate with the Sahara regions, while Central Europe was governed by a temperate subtropical climate. For this reason, areas which had similar climates had similar vegetation communities. However during the tertiary period, the Gondwanaland broke up slowly by slowly and continents occupied the present positions. Several changes took place, for this led continents to occupy latitudinal belts into which the earth's climate was differentiated as it is today. Vegetation communities underwent many changes and some got exterminated due to change of climate. Some remnants of older flora had managed to escape extermination by occupying sheltered habitats or by developing biotypes tolerant to the changed conditions. Acacia tortilis ssp. raddiana and ssp. tortilis fall among the vegetational community of Israel and Jordan which are remnants of the past flora before the climatic and floristic changes.(Zohary, 1962). They fall among the tropical element which probably dominated the southern Mediterranean during the miocene and retreated in the pliocene period. Ssp. spirocarpa and ssp. heterecantha must have moved from the north of Africa (The East Sudan) to the south since South America and Australia which were in contact with Africa to the West and East respectively, do not have any of the subspecies of Acacia tortilis.

Throughout its distribution, Acacia tortilis occupies savannah areas, semi desert to desert regions. All the subspecies need adequate water supply and therefore occupy regions which are near rivers (ssp. heterecantha ssp. spirocarpa) or wadi beds (ssp. raddiana and ssp. tortilis). Acacias are light demanding (Elamin, 1976) and they can tolerate high temperatures and humidity (Zohary and Orshan, 1956). The subspecies of Acacia tortilis occupy hot regions with maximum sunlight and yet with adequate supply of water. The southern part of Sudan is not much occupied by Acacia tortilis for there is a closed forest and since the Acacias prefer maximum sunlight, which they cannot get there, they are restricted by the forest (Elamin 1976) and those which are there, have to fight very hard to shoot up for light.

4.3 The dispersal of Acacia tortilis

Animals form the major factor of seed dispersal of Acacia tortilis, for they feed on pods; and seeds passed out in their dung after being softened in the stomachs (Elamin 1973, Halevy, 1974). Domestic animals are moved by nomads across dry areas lookig for pastures. and seeds of Acacia tortilis are dropped in various places during the movements. This has contributed to the distribution of ssp. raddiana across the Sahara desert and along the dry areas of south of the Sahara. In East and south Africa, most subspecies of Acacia tortilis occur in Game reserve areas.In these regions, wild animals have contributed more towards the dispersal of Acacia tortilis. Human beings play a part as well in distributing this species in various places especially during the dry season, when pods are sold in markets or when they are eaten in Kenya by the Masai tribe and in Somalia (Peck 1941). Trees of Acacia tortilis are usually cut for various purposes and branches are carried to certain distances where they will be used. In all these processes, pods are dropped in various areas.

Following the migration route of Acacia tortilis from Sudan to the west, north and to the south there are ~~the~~ various gaps which cannot be explained fully. However, there is a seed beetle (Bruchid) which feeds on seeds of Acacia tortilis. This beetle has been a threat to semi-arid areas where Acacia tortilis is found, for it is believed that it can create a desert. There are various species of the seed beetles and they show some variation in their life cycle. The infection of the seed beetle inflicts almost total destruction of Acacia seeds. In Acacia tortilis, the infection frequently results in an attack on 99 per cent of the seeds (Southgate 1974, Halevy 1974). Some gaps in the distribution of Acacia tortilis can be accounted for this seed beetle, but noone knows the effect of damage, by the larvae to the potential seedlings' cotyledons. The seeds of Acacia tortilis have a hard testa which need to be softened before it can break and then germinate. Seeds which have passed through the stomachs of animals germinate faster than those which have not. Occasionally seeds which have been attacked by Seed beetles but only slightly germinate easily because the scar allows efficient uptake of water essential for germination. (Southgate,1978). Lamprey (1967) found out (in the Tarangere Game Reserve in Tanzania) that seedlings of Acacia tortilis could only be found growing from faecal pellets of the Impala. He obtained no germination of seed from fallen pods, while 7% germination was collected from faecal pellets, Lamprey therefore believed that passage of seeds through animals is necessary for re-generation. With such a process, there is a balance and a restriction in the distribution of Acacia tortilis.

The movement of Acacia tortilis from the Sudan to the south is difficult to explain, but it must be associated with migrations of people down to the south in the past years. History tells us that the earliest people in Africa lived in the Sahara regions before the area was dessicated around 2,000 BC and they helped to form the early populations along the Nile. From here they gradually dispersed southwards. (Europa Publications, 1974).

Eastern Sudan forms one of the earliest sites where civilisation took place and pastoralism had been in the region from at least 3,500B.C. However, this may probably be a long time to account for the movement of Acacia tortilis down to the south, but the influence of trade in gold from West Africa, South Africa and other materials may have affected the distribution. The trade routes from the interior to various places around the coast or around areas near the sea and rivers were common across the whole continent. There may be some other possibilities to account for the distribution of Acacia tortilis down to the south but the fact is true that they have sucess-fully occupied the open savannah areas south of the Sahara.(Figure 4.5)

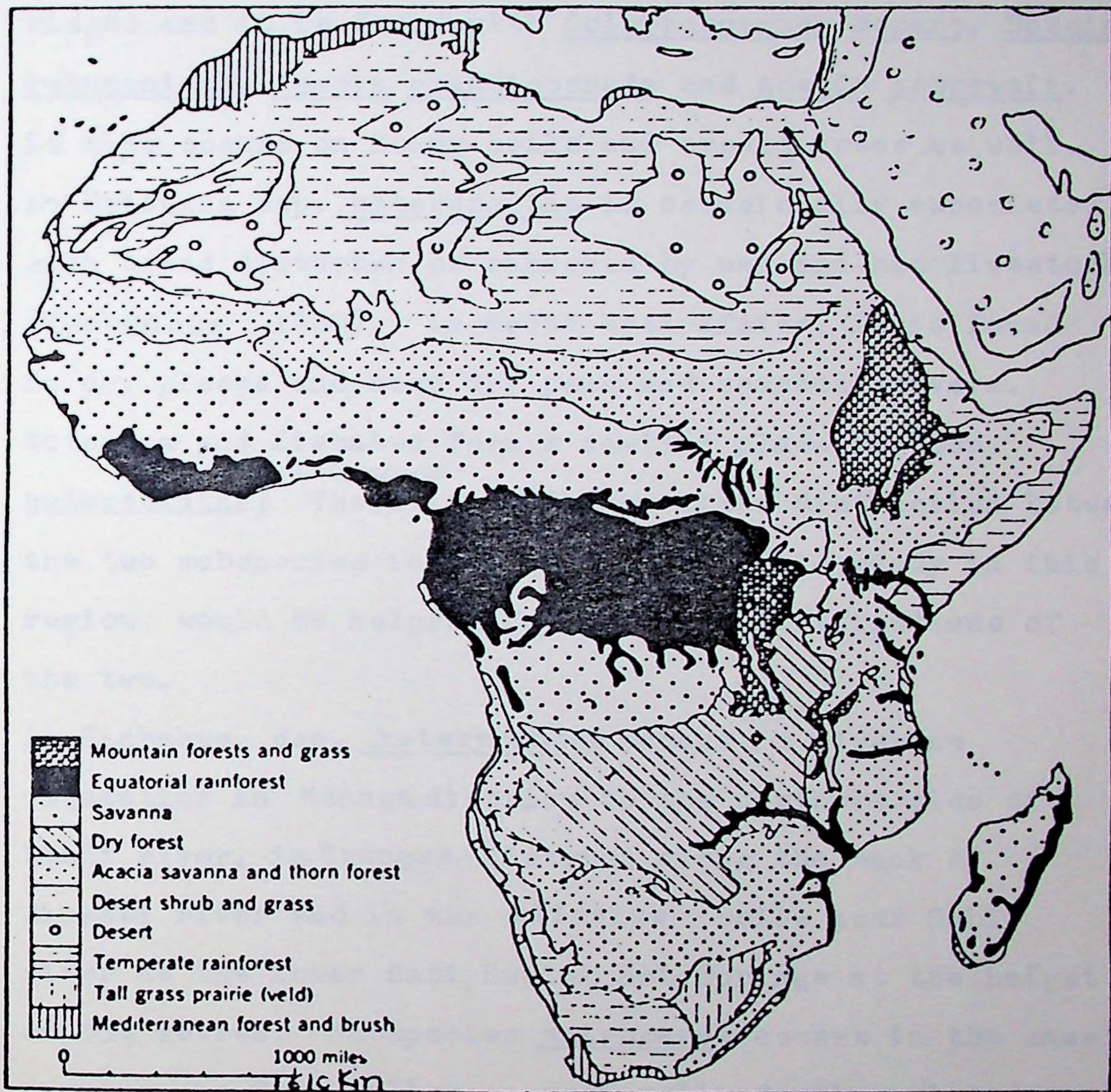
4.4 Ecological Factors

Acacia tortilis may be considered to have a wide range of habitats from the river fringing vegetation to open Savannah lands and to dry sands in the deserts. It is found in natural meadows in higher altitudes of East and Central Africa, in grey brown soils derived from sand dunes in the northern parts of West Africa, in depressions of Lake Chad the and inland Niger delta.

In the Republic of South Africa, ssp. heterecantha is distributed in the bush and low veld vegetation of Transvaal, Natal and Orange Free State. In Transvaal it is found in gravelly loam soils along water courses or river banks. In Natal it is found on brown sandy soils in association with Acacia nilotica, Dichrastachys

Fig. 4.5

The Vegetation of Africa and some parts of the Middle East (Dudley Stamp 1952)



cinerea and Mayterius senegalensis. The area is a bit hilly in this region.

In Botswana, it is associated with Lake pans on stony ridges and it is found with Colophospermum mopane, Boscia rehmanniana, Acacia grandicornuta and Acacia nebrownii. It also occurs on loamy soils and eroded areas as well. In Botswana ssp. heterecantha is occasionally associated with areas disturbed or enriched by man and his livestock (Timberlake 1980). In South West Africa, it is found in dry places and near dry pans and seasonal rivers. Botswana and Zimbabwe form a meeting place for ssp. heterecantha & ssp. Spirocarpa. There is hardly no clear distinction between the two subspecies in the region and field study in this region would be helpful for further clarifications of the two.

In Zimbabwe, ssp. heterecantha occurs in riverine vegetation in Ndanga district to the northern side of Lundi river, in Urungwe district along the bank of Sanyati river and in the alluvium soils near Sabi river at the lower Sabi Rupisi Hot Springs at the height of 534 metres. Subspecies spirocarpa occurs in the same country, in Sabi valley occassionally forming closed forests, yet elsewhere it is in open bush. It also occurs in the Mtoko district at 915 metres near a river then in Sabungwe district along Lusu River. In Zambia ssp. spirocarpa var. sporocarpa is again associated with the tributaries of river Zambezi around Chirundu in Mopani woodland (a type of woodland in the hot dry conditions of the Zambezi valley region) and along the Luangwa river at Kakumbi associated with Acacia ataxacantha, Combretum obovatum, Capparis tomentosa in old cultivation areas. The tree is found in Malawi as well, in Karong Rumpe and Mangochi district in the Savannah grassland with Acacia ziziphus. It is found along the course of Lake Malawi.

Both ssp. spirocarpa var. spirocarpa and var. crinita are very well distributed in the dry savanhah lands and woodlands of Tanzania and Kenya: Subspecies spirocarpa var. spirocarpa is found in the Shinyanga area especially in the south and in large areas bordering the Wembere steppe; in the rift valley; in the Masai steppe, in the neighbourhood of the Irangi escarpment and southward to Mbeya in the Usangu plains and the Rukwa depression in Tanzania. (Burtt-Davy 1946). Away from the great plains of Wembere, Serengeti and Masailand, var. spirocarpa is found fringing seasonal rivers such as Bubu in Kondoa, the Tubungwe - Matamondo rivers of Mpwapwa district and the larger rivers that flow to Lake Victoria. The soils near these rivers is alluvial sand and silt but in plains it is the grey sandy clay type setting hard in the dry season. The variety occurs near Lake Manyara in association with Balanites aegyptiaca and Cardia gharaf at 1067 metres on well drained slopes. In Iringa district, it is associated with tree like Adansonia digitata, Acacia claugera ssp. usambarensis, Acacia nilotica ssp. subalota, Balanites aegyptiaca Combretum apiculatum, Maerua crassifolia and grasses like

Urachloa trichopus, Bracharia deflexa, Dactyloc:terium giganteum and Panicum maximum.

Acacia tortilis ssp. spirocarpa var. crinita occurs in the Shinyanga region, Rukwa depression and Musoma district, where it is dorminant in the woodlands of this region occasionally with Acacia clavigera ssp. usambresins scattered in Thylachirum africanum and Grevia fallax. The grass species found in association with it are Chloris myrostachya and Digitaria species. There are local forms of var. spirocarpa occurring in Shinyanga, Serengeti and Musoma regions. They have wider pods which have warty surfaces and the pods are not contorted. (See Figure 3.9)

In Kenya ssp. spirocarpa var. spirocarpa occurs in the Masai land and is much more associated with the rift valley and outside the valley, on the recent volcanic rocks. The variety dominates the Machakos area and many local forms occur here with straight and slender woolly pods and those with warty pods as well and they are not twisted. There are also forms with sparsely pubescent pods. In the region of Lake Baringo, the same local forms exist while there are also many usual forms of var. spirocarpa. In this region var. spirocarpa is associated with Acacia elatior ssp. elatior, undergrowth shrubs of Acalypha fruticosa all forming the riverine woodland. In Garissa district near River Tana region in Kenya, var. Spirocarpa occurs as dry woodland along the river bank, scattered with Dobera glabra, Garcinia livingstoneii, Terminalia species, Diospyros consalatae, Populus ilicifolia, Acacia elatior, Commiphora species, Hunteria cordiagoetzi, Diospyros mespiliformis, Sorinderia madagascarienskis and Terminaria parvula.

In the northern province of Kenya around Moyale, the variety is associated with Cussonia species, Ficus species, Combretum, Commiphora and Dichrostarchys species. The soil here is quite deep and of a sandy loam type.

Acacia tortilis ssp. spirocarpa var. crinita occurs around Machakos plain, Yatta and Makueni 64 kilometers south East of Machakos. Subspecies tortilis occurs in the dry Turkana regions and Tsavo national park. Subspecies raddiana var. raddiana may have just been introduced there and in Somalia as well where it is associated with ssp. tortilis on the southern coasts of the Gulf of Aden.

In Ethiopia ssp. spirocarpa, ssp. tortilis and local forms of spirocarpa do occur around the Awashi region in the Shoa Province and around Langano in the rift valley.

In the central and north eastern Sudan all the subspecies of Acacia tortilis are found except ssp. heterecantha. The south eastern part near the border of Uganda and Sudan seem to be holding ssp. spirocarpa only. Acacia tortis, occurs along the River Nile and its tributary and along seasonal Valleys on sandy loamy soils in the Savannah grassland and scrub in the semi-desert and desert plains. In these regions of the Sudan, the desert vegation is confined to the Nile and to such great water courses as the Wadi el Howar in Darfur or the Wadi el Melik and Wadi Muqaddam which drain northern Kordofan and the Beyuda desert. In these stream beds, coarse grasses do occur among which the subspecies of Acacia tortilis are found.In the semi desert area, the region between the desert and the low rainfall woodland savannah, the subspecies of Acacia tortilis again appear as desert scrub associated with Maerua crassifolia and the height of the trees is usually between 2-3 metres high.

In Uganda, subspecies spirocarpa var. spirocarpa occurs in the riparian thicket of Karamoja in the North Eastern part of the country. The vegetation of this unit consists of various communities on the banks of rivers which flow for short periods after rain in the east and central Karamoja. They are found at altitudes of 1220 to 1524 metres, with mean annual rainfalls of 508mm to 762mm. In this region Acacia tortilis ssp. spirocarpa var. spirocarpa is associated with Acalypha volkenzii, Euclea schimperi and Maytem buxifolius (Langdale,1964). In the east-central Karamoja ssp. spirocarpa var. spirocarpa occurs again in association with Lannea humilis, L. triphylla Aristdia adscensionis, Barteria longissima, Panicum massaiense and Sporobolous festivus. The unit is made up of scattered trees and shrubs with a low, open, perennial grass cover.

Acacia tortilis ssp. raddiana var. raddiana occupies wadi beds where it forms a closed vegetation. It is frequent along the course of the Gulf of Suez and the Dead Sea. In Northern Nigeria it occupies areas near

Lake Chad, in the hot arid wooded savannah region on dark coloured heavy clay-sandy soils. In Mali Republic it occupies the sandy bank river valley around the region of South Gao and Goundam, in the subdesert wooded savannah. In Ghana it is found in the south of Wiaga on the road to Uwiasi in the mild sub arid wooded savanna. This is a zone which receives between 750-1000mm rainfall distributed over a period of 120-140 days of the year. The region is open woodland with tall grass dominated by *Hyperrhania* species, *Brachiaria* species and *Cymbopogon giganteus.* In Libya the subspecies is confined to areas near oases.

Subspecies *tortilis* is limited to hot and dry rift valleys except where it occurs with ssp. *raddiana* in the region of northern Negev where rainfall exceeds 150mm.

Subspecies *raddiana* var. *pubescens* is a rare variety and its distribution is difficult to explain. It occurs in the central and eastern Sudan and in Bornu district in the north east corner of Nigeria and it also occurs in the Bahrain state and in Yemen.

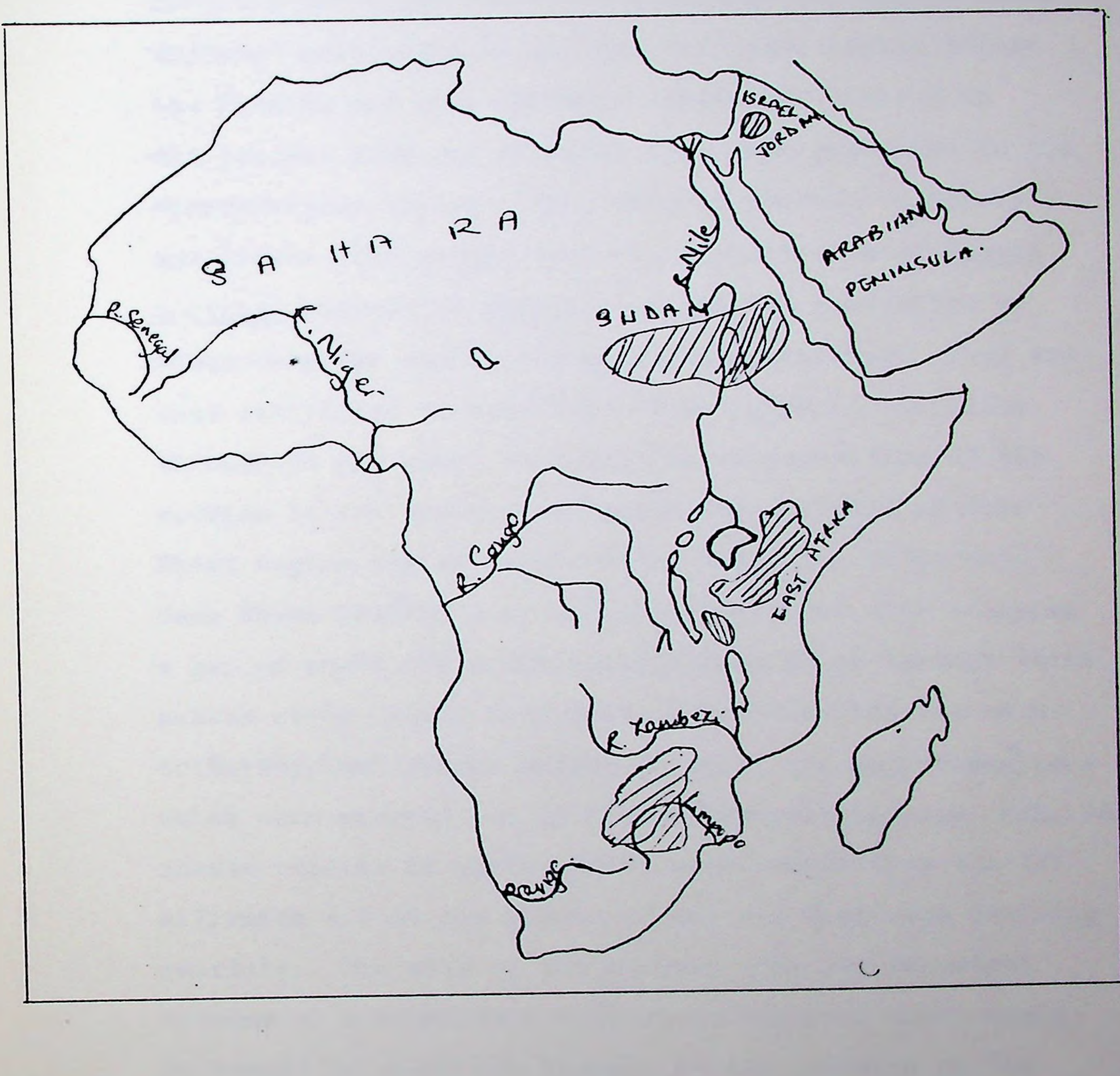
Although *Acacia tortilis* occurs in dry hot climates it is found in close association with water in those habitats where it is found.

4.5 Areas of species richness

There are four major areas which show richness of one or two of the subspecies of *Acacia tortilis* (Figure 4.6). The region around Beer Sheva in Israel is rich in subspecies *raddiana* and probably the Negev region in the same country. Halevy and Orshan (1972) carried out exhausitive work on the distribution of this

Fig. 4.6

Areas dominated with <u>Acacia</u> <u>tortilis</u>



subspecies in Israel. It is true that until such studies were carried out, _Acacia tortilis_ subspecies _raddiana_ could be considered native in the region. Zohary in 1962 was the first one to suggest that the _Acacia_ trees migrated northwards in the Mediterranean region before the Miocene and that climatic conditions similar to the present Sudanian climatic type then prevailed in the Mediterranean region. Then further studies of Halevy and Orshan 1972 showed that the distribution of _Acacia tortilis_ subspecies _raddiana_ is greatly controlled by adequate water supply and higher temperatures. They are thus restricted to Wadi beds where water is available throughout the year. However the concentration of the species in the western and south western part of Beer Sheva region may be an effect of something different. Beer Sheva itself is an ancient town whose site occupies a gap of about 5Km width between chalk hills through which passes river Nahal Beer Shava which receives its main tributary,Nahl Hebran before entering the gap. Excavations which were carried out in 1954 by J.Pevot (Europa. Pub.1961) showed remains of agricultural settlements from the 4th millenium B.C on the flanks of the old Wadi with dwelling quarters. The site of the ancient town was important because of a relatively rich water horizon, which could be tapped by wells and because of its position on the gap which formed the main gate from the coast and Judean mountains to the Negev and southern end of the Dead Sea.

The resources used to be insufficient for irrigation and their main use was then for flocks of migrating sheep. In this capacity the site also entered Jewish history as the dwelling place of the Patriachs.. The region was a meeting place of several communities and thus it has harboured a lot of history and heritage. It is very difficult to associate such history with the richness of subspecies raddiana var. raddiana in this region but in one way or another it must have a connection. Human and animal movements could involve the carrying of the pods, seeds and wood of Acacia tortilis to this place either internationally or not, and the species got a connection to that place. In fact subspecies raddiana is grown for fodder now in Israel both in the Negev and this region around Beer Sheva. Karschon 1961 mentioned that thirty years ago caravans transporting charcoal from Wadi Araba as far as Beersheba were a common view in the desert. This may have contributed to the collection of this subspecies in the same region

The Central and Eastern Sudan is another area rich in the subspecies of Acacia tortilis. It is an area suggested to be the dispersal centre of Acacia tortilis for it shows the maximum morphological diversity of Acacia tortilis. This is a region in the desert where there is a supply of water and this means that it is a collecting place for both people and animals and plants as well. It is an area where pastoralism has been present for quite a long time and it is a site where

most old trade routes converged long time ago. The exact region where the subspecies of _Acacia tortilis_ are concentrated is the Kassala area , Wadi Medani and northern Kordofan regions.
Throughout the Sudan, there is a broad correlation between the amount of rainfall and the height, diversity and thinkness of vegetation it supports. As the mean annual rainfall decreases from 2,000mm in a few mountainous parts of the extreme south to virtually nothing along the northern frontier, so the vegetation declines from a few patches of tropical rainforest through broad leafed savannah, _Acacia_ woodland and _Acacia_ desert scrub to desert which supports no plant life at all. However, some particular tree species are found in areas with very different rainfall total and with widely different types of soil and sites that vary from the tops of stony hills to the bottoms of clay lined depressions. _Acacias_ of the Sudan fall among these tree species. _Acacia tortilis_ in the Sudan occurs in the semi desert scrub, and dry grass savannah. Occasionally it occurs in the desert part as well.

The Masai steppes of East Africa, the Serengeti plains, the Usangu and Rukwa flats in Mbeya, Tanzania and the Machakos area of Kenya are rich in ssp. _Spirocarpa_. These places are dry but they are associated with volcanic soils around the rift valley regions. The altitude is a bit higher than that in the Sudan and the Sahara regions. This may be associated with the development of hairs in this subspecies. These regions are occupied by tribes which have been nomads for a long time especially the Masai. This subspecies is therefore utilised fully by both man and animals. The same regions are occupied by Game reserves where wildlife is totally dependant on this tree in the dry season. The tree has various uses in this region (see chapter 6) and there is a probability of it being conserved in both Kenya and Tanzania.

The regions of bush veld and low veld in Transvaal and Natal are rich in ssp. heterecantha. It is common in Kruger game reserve. The natives of Natal use this tree in many ways while animals of the game reserve also feed on this subspecies. Domestic animals also feed on these pods, frequently.

CHAPTER 5

TAXONOMIC DISCUSSION

The results drawn from the morphological study and scatter diagrams indicate a close relationship that exists among the subspecies of Acacia tortilis. However, ssp. raddiana is distinct from other subspecies by its dark red glabrous branchlets, glabrous pods and habit. Subspecies heterecantha and ssp. spirocarpa can be distinguished with difficulty because the degree of pubescence in the different parts of the plant is not constant. The glands on pods and petiole is also not constant. Subspecies heterecantha is usually recognised by the shortly pubescent brandchlets, petioles and leaf rachis plus pods as well, while ssp. spirocarpa var. spirocarpa has long hairs on pods, branchlets and petioles. The pods of ssp. spirocarpa are wider as well than those of ssp. heterecantha and they are less coiled. In regions where ssp. heterecantha and ssp. spirocarpa occur together (Botswana and Zimbabwe), it is very difficult to distinguish them because some have wider pods and yet not densely pubescent while others have smaller pods, twisted and with dense short hairs as well. However, the pod surface of ssp. heterecantha has provided further distinctions by having straight papillate hairs and micro ridges on the pod while ssp. spirocarpa does not show obvious ridges and the hairs are curved at the top, though they are papillate.

Ross in 1979 mentioned that the indumentum of various organs diminishes with age in some species. This may be true with ssp. heterecantha and ssp. spirocarpa.

However before any conclusion can be drawn, it is worth considering some of the work which has been done on some of these subspecies in order to support or not, the conclusion of the study.

5.1 Morphology

A number of workers have dealt with the morphological variation of *Acacia tortilis* (Andrews 1952, Brenan 1957 1959, Tackholm 1974, Ross 1979). The list cannot be exhausted. They all recognised ssp. raddiana as having glabrous pods, branchlets and leaves. Subspecies raddiana is a tree with a round, crown. (Tackholm, 1974, Elamin 1973, Karschon 1961, Halevy 1974, Zohary 1962). Subspecies heterecantha is recognised as a tree with glabrous to shortly pubescent pods, shortly pubescent branchlets, petiole and leaves, pods without glands, whereas subspecies spirocarpa is considered to have longer hairs than those of heterecantha on pods and young branchlets, pods with dark red glands. Pods of subspecies spirocarpa are less coiled which agrees with the study of Robbertse (1975) and Timberlake (1980), subspecies raddiana is usually considered to have the widest pods but according to this study ssp. spirocarpa var. spirocarpa has wider pods than ssp. raddiana. There is an overlapping of characters in ssp. heterecantha and ssp. spirocarpa var. spirocarpa. especially in the degree of indumentum and pod width. However, ssp. spirocarpa var. crinita. is distinct enough by having long silvery white hairs from 1-3mm long on the pods, petioles, peduncles and leaf rachides. The hair is not papillate . There are some forms though which have few long silvery hairs scattered on the pods (Peter 42674) and those with heavy dense long silvery hairs (Newbould 5817, 1961) (Figure 3.9). Morphology alone cannot distinguish the subspecies of Acacia tortilis because some specimens cannot be placed in any group with certainty. On the other hand morphological studies should be done in the field as well for comparisons with the dried specimens, in order to achieve successful results.

5.2 Cytology

Vassal (1974) gave a report on chromosome number for so many species of Acacia. Several of the chromosome counts which were listed by Vassal were based on the work published by Hamont, Lescanne and Vassal (1975). Although most species with capitate inflorescences were found to have 2n = 52 where ssp. heterecantha and ssp. spirocarpa are included, there were some which had diverging numbers from 52 like ssp. raddiana which had 2n = 104. This is another big difference between ssp. raddiana and other subspecies.

5.3 Palynology

Zinderen Bakker and Coetzee (1959) examined a number of pollen grains of the African Acacias and they consisted of compound grains of 16 cells. It was only *Acacia giraffe* which had from 26 to 48 cells.

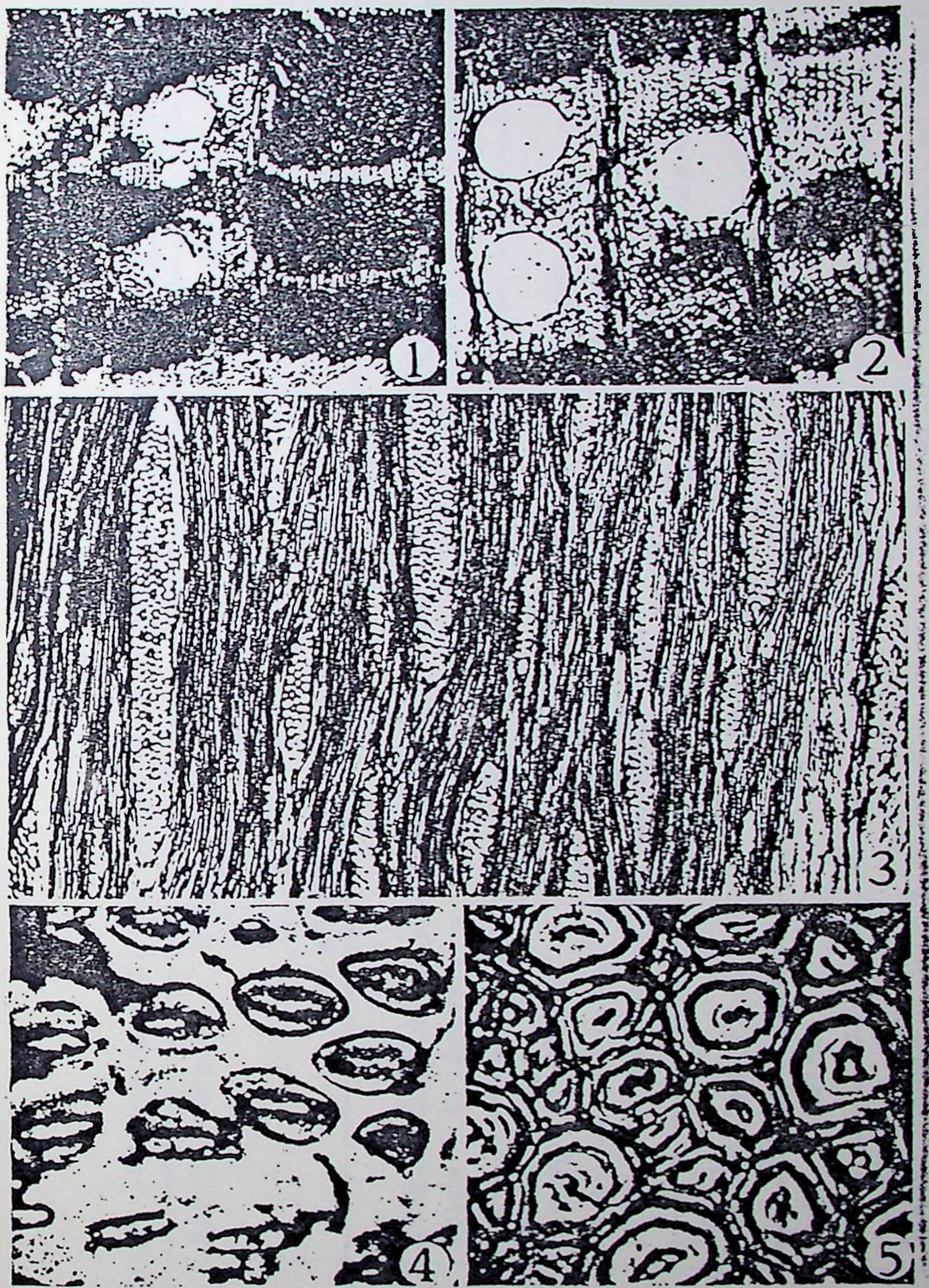
5.4 Anatomy

Robbertse (1975) reported on the anatomy and morphology of the pods. The pods of his ssp. *spirocarpa* are not twisted but curved like some local forms which are found in Machakos area of Kenya. He reported that pods of *Acacia tortilis* are sluggish in opening and usually remain closed when they are dry. He also reported that ssp. *heterecantha* has papilliform hairs which agrees with the scanned pods of this study. Anatomy was carried out on the structure of the abaxial or outer epidermis of the pod. He found out that the parenchymatous stratum in the margins of the pods of *Acacia tortilis* is collencymatous. Fahn (1959) carried out an investigation in the xylem structure and annual rhythm of development in *Acacia tortilis* (ssp. *tortilis*) and A. *raddiana* (ssp. *raddiana*). Both subspecies were found to have a diffuse porous wood with indistinct growth rings. There was a close similarity in the wood structure, the only distinguishing feature being the broader concentric bands of confluent wood parenchyma in ssp. *raddiana* (Figure 5.1). There may be some information on the anatomy of wood for ssp. *spirocarpa* and ssp. *heterecantha* but could not find it.

5.5 Chemistry

The chemical composition of gum found in ssp. *heterecantha*., ssp. *spirocarpa* and ssp. *raddiana* var.

Fig. 5.1



A.tortilis - cross section of wood (Fahn 1959)

1. A. tortilis (ssp tortilis) cross section of wood X52
2. A. raddiana (ssp. raddiana) cross section of wood X52
3. Tangential section of wood. A. tortilis X80
4. Intervascular vestured pits X1850 A. tortilis
5. Cross section of wood showing Fibres with inner gelatinous layers A. raddiana X820

TABLE 3:

Chemical composition of Leaves, Pods and Seeds of Ssp. heterecantha and ssp. spirocarpa (Russel 1947)

Botanical name	Plant	Source	Moisture content of material percent	Pretein Crude %	True %	Ether. extraction % age	Crude %	Ca %	Mg %	Na %	K %	Fe %	P %	Cl %	S %
Ssp. heterecantha	Pods	S. Africa	-	17.3	-	3.1	24.8	0.79	-	0.23	1.32	-	0.34	0.12	
	Seeds	S. Africa	-	8.7	-	1.6	34.3	1.10	-	0.32	1.50	-	0.14	0.13	
	Fresh Leaves	Cape Province	-	19.2	-	6.1	11.6	2.27	0.46	-	-	-	0.17		
Ssp. spirocarpa	Pods	Tanzania	10.0	13.3	-	8.3	9.4	4.00	-	-	-	-	0.15		
	Fresh Leaves	Sudan	9.1	16.6	-	2.5	32.7	-	-	-	-	-	-		
	Pods	Sudan	9.3	8.4	-	0.6	25.9	-	-	-	-	-	-		
	Fresh Leaves	Sudan	12.5	9.1	-	1.3	41.6	-	-	-	-	-	-		

pubescens was investigated by Anderson and Bell (1974). The overall impression was that ssp. *raddiana* var. *pubescens* was intermediate between ssp. *spirocarpa* and ssp. *heterecantha*, but on the basis of their visicosities, molecular weights, methoxyl and rhamsone contents, ssp. *raddiana* appeared to be closer chemically to ssp. *spirocarpa* than to ssp. *heterecantha.* Russel (1947) reported the chemical composition and digestibility of ssp. *heterecantha* and ssp. *spirocarpa*.(See Table 3)

5.6 Physiology

Measurements of transpiration and osmotic pressure of *Acacia tortilis* in Wadi Araba in Israel had been reported by Zohary and Orshan 1949. Subspecies *tortilis* was shown to have a higher transpiration rate than ssp. *raddiana*. The hairy nature of ssp. *tortilis* helps in regulating the amount of water being lost to the atmosphere. Subspecies *tortilis* was found to be more salt and draught resistant than ssp. *raddiana*, while ssp. *raddiana* can tolerate lower temperatures in winter than ssp. *tortilis*.

5.7 Phenology

Both ssp. *raddiana* and ssp. *tortilis* show differences in phenology. Ssp. *raddiana* shows winter dormancy at higher elevations and flowering occurs in June to January. Subspecies *tortilis* flowers from May to September (Halevy and Orshan 1973).

In all this, a substantial amount of work has been done on both ssp. *raddiana* and ssp. *tortilis* in Israel and Sudan, but the work on ssp. spirocarpa is little compared with ssp. raddiana, tortilis and heterecantha. While there are many reasons for some workers to prefer separating ssp. raddiana, as a species, there is not enough evidence from other subspecies to.support the difference.

Subspecies raddiana is a tree with a round crown (Chaudhary 1982 (personal contact), Elamin 1973, Tackholm 1974). It is a polyploid with 2n = 104.
It has broader concentric bands of confluent wood anatomy and it has red glabrous branchlets, glabrous pods and leaves.
The chromosome number is a strong factor because it may be responsible for the distribution of ssp. raddiana in hotter and drier regions than the rest of the subspecies. It has already been introduced to India and it is doing very well. Severe climates induce polyploidy.
(Grant 1971). It can withstand cold winter more that ssp. tortilis.
The chromosome number of ssp. tortilis has not been found for comparison.
For best comparison with other subspecies it is better to study the range of variation of all the subspecies of Acacia tortilis in the field. Secondary ssp. raddiana should be grown in different environments to see the effect of the environment on particular characters like habit and crown.

Subspecies heterecantha and spirocarpa var.

spirocarpa can also be studied in other aspects besides morphology to confirm their differencies and to study their ecology as well.

CHAPTER 6

THE UTILISATION OF *Acacia tortilis*

6.1 INTRODUCTION

With the increased knowledge of plants many plants have been found to be economically useful. *Acacia tortilis* has not only caught the attention of the taxanomists but the ecologists and the economists are busy dealing with the species. The species has no outstanding position in the economy of any country yet its importance in the arid lands of Africa and the Middle East cannot be ignored.

The pods and leaves provide a good fodder for domestic animals and wild-life during the dry season. They are also used for many local medical purposes in Africa. The tree can produce gum which is used locally and timber is used for furniture, buildings, agricultural equipments, for firewood and charcoal. Tannin for leather industry is produced from the bark and pods. Ropes and strings are products from the bark, local pins, from thorns, local necklaces from pods and paintings from flowers. The canopy provides shades in deserts; and soil reclamation measures use *Acacia tortilis* to stabilise sand dunes. For these and other uses, *Acacia tortilis* is worthy of a comprehensive study, for there is hope that it will be a promising tree for arid and semi arid lands.

6.2 Forage plant

Forage shrubs and trees are woody plants that provide feeds for livestock and *Acacia tortilis* forms one of the major forage shrubs and trees on which animals browse in semi-arid areas. The leaves on young trees are browsed by camels, goats and sheep especially in the north western Sudan (National Academy 1979). Among the dry savannahs, wild animals like the Impala, duiker, eland, giraffe and sheen-buck feed on the leaves as well. Camels among all these animals seem to favour leaves of *Acacia tortilis* subspecies *raddiana* more than other animals since most of the camels' food is woody vegetation. Camels are still of economic importance in the Sahara desert and subspecies *raddiana* is one of the commonest tree in the region.

The pods are of most value as fodder. For it was proved that pods have a very high nutritional value; 18% protein, 2-4% fats, 46% carbohydrates, 5% minerals and 20% roughage (National Academy 1979).
The tree produces numerous pods and throughout Africa, in arid areas, pods form the main, source of food for domestic animals and wild life during the dry season(January to February in Kenya),(National Academy 1979). Pods are the main sustenance for much of East Africa's wildlife. Generally the dried pods are eaten off the ground but sometimes they are picked off the tree by animals. Natives of Somalia pick the pods off the tree during the dry season and they sell them in the market. In South Africa

cattle prefer pods of ssp. heterecantha to other pods. (Palmer and Pitman,1961).

The pods are not only eaten by animals but human beings eat them in various ways. In Somalia,the dry pods are eaten either raw or they are made into porridge. In Kenya, the Masai tribe make tea from pods, yet still; soup is made from pods and is used as medicine for stomachaches and headaches. The seeds are always removed when pods are going to be eaten or cooked, for they are bitter. In South Africa, natives make necklaces from pods and they can be interwoven to make various designs in order to produce good necklaces.

Flowers are eaten by baboons both off the tree and off the ground in Kenya probably they get attracted to flowers because of the pleasant smell they have. In South Africa, monkeys and baboons eat the green seeds from the pods (Wyk,1972).

6.3 Gum Producer

The Leguminosae has been suggested to be the most potentially important gum yielding family; for many plants of this family produce gums either from their seeds or from their bark. (National Academy, 1979). Over a hundred species of Acacias are known to exude a certain amount of gum when their bark is damaged and yet they grow in non hospitable areas where conventional agriculture is not feasible and where poverty is common.

Acacia tortilis produces some amount of gum. It does not produce gum which is commercially available but its gum is used locally. Morocco is one of the countries in which an export of gum trade has existed in the past, and there was a belief that *Acacia tortilis* subspecies *spirocarpa* was one of the gum yielding tree in the area (Howes,1949). However, it is surprising that the subspecies of *Acacia tortilis* seem to be rare in Morocco especially subspecies *spirocarpa*. In Tanzania *Acacia tortilis* subspecies *spirocarpa* is one of the *Acacia* species from which it was thought gum might be extracted for export but the problem was that the tree does not produce gum freely. *Acacia drepanolobium* might have proved better than the former (Howes,1949). However, gum is locally used in Somalia, East Africa and Sudan and on some occasions it is mixed with other gums to produce a better quality gum to be used in various ways. This gum is usually from ssp. *spirocarpa*.(Glickman and Sand,1969) Gum is a sticky substance which dries into a brittle mass that swells in water. It is a microbial polysacharide and it is dispersible in cold or hot water to produce viscous mixtures or solutions. (Glicksman and Sand 1969). Gum is formed from parenchymatous elements in the pericycle and phloem of wood. (Metcalfe and Chalk 1965). Gum from

Acacia tortilis is pale or almost white and it is produced from the bark of the tree when wounds are made by man or made naturally. Incisions in the bark are made by a small axe and the bark is then peeled to form a rectangular wound. Gum collects in the wound within a few weeks depending on the weather and the subspecies. Gum gradually dries and hardens on exposure to the atmosphere. It is collected by hand from the wounds and is brought to villages where it is stored until there is plenty of it to be transported to market centres. Gum is usually collected.during the dry season. Many wounds are made on the tree in different spots and the tree is not harmed for eventually the wounds get healed, ready for further incisions.

Although *Acacia tortilis* does not produce commercial gum, it is important to know the use of gum for purposes of creating incentives for improving the quality of *Acacia tortilis* in various areas. Gum has a major function in food industries as a confectionery because of its ability to prevent crystallisation of sugar and also because of its thickening power. It can also be used as a stabiliser in frozen products such as icecreams, ices because of its water absorbing properties. It is used in baking industries for its viscosity and adhesive property. It can be used as a fixative for flavours. Gum is used in phamaceuticals because of its emulsifying and stabilising properties and it can act as medicine. In cosmetics gum has a place, in adhesives gum has been widely used, paints and ink need gum, while textiles also need it. There are all sorts of various uses of gum and therefore investigations in gum properties of Acacia tortilis should be carried out and a possibility of breeding for better quality gum and yield should be investigated.

6.4 Timber for fuel and charcoal

The use of wood as fuel for heating and cooking dates back to the earliest days of man's conquest of his environment. It remains a main benefit from the forest in all the less developed countries even today. Wood was widely used for firing pottery and bricks in simple kilns. Charcoal is also still used today. Acacia tortilis has a very hard wood when it is dry and it contributes towards various purposes. It can make excellent durable fence posts (ssp. heterecantha). The red heart wood of ssp. raddiana has a high calorific value (4,400Kcl per Kg). (National Academy 1980) and makes superior firewood, and charcoal. It is one of main firewoods and charcoal used in Sudan. Acacia tortilis ssp. raddiana was introduced to India from Israel and it grows so well in the region of Rajasthan and plantations are being established for fuel wood. (Skerman, 1977.)
Wood is used for manufacturing small implements and articles, it is used in making dhows (the rib parts) and the wood can be excellent for wagon-building, and for furniture buildings.

6.5 Tannin Producer

Acacia tortilis subspecies *spirocarpa* produces a substantial amount of tannin in Tanzania. It contains 10.4% of tannin (Tothill 1940). In 1980 a report was submitted on two native trees in Uganda which were thought that they would contribute towards tannin export (Tothill 1940). These were *Acacia tortilis* ssp. *spirocarpa* and *Terminalia velutina.* However, they were later not considered of value for exporting tannin from them, although they are used locally to produce tannin. Tannin is a yellowish, astringent substance and it is used to cure hides into leather by soaking hides in it. It consists of uncrystallible colloidal substances which are astringent and which can precipitate gelatin from solution and also to form insoluble compounds with gelatin yielding tissues. Because of this property, tannin is able to cure hides and skins into leather. Tannin is extracted by grinding the bark or wood or any other plant tissue which is suspected of containing tannin. The ground material is then shredded or reduced to a fine state to allow as much extraction as possible using hot water. The solution which is acqueous now is allowed to concentrate or evaporate to dryness and is then ready for sale in liquid or more usually in solid form. This is all done by hands but on large scale industries, most of these processes are done by machines. In Tanzania and

Uganda tannin is produced locally so it is done by hand.
Tannin is used for making all types of leather materials and it forms quite a big industry in the world today.

6.6 Miscellaneous uses

In many parts of Kenya, Tanzania and Zambia the young bark of Acacia tortilis ssp. spirocarpa is used in making local ropes and strings. It is the inner side of the bark which is soft enough to be incorporated into ropes and strings.
The thorns of Acacia tortilis are long and slender enough to be used as pins especially in East Africa. They are used to dig jiggers from the feet and also to dig other thorns which got stuck in the skin. The tree is also used in witchcraft whereby thorns are stuck in the goat's pancreas to blind any man who has been considered as having the evil eye (Kokwaro, 1976).
In deserts, the tree has been an excellent sand dune stabiliser. In Rajasthan, India, over 800 hectares of shifting dunes have been stabilised by planting the species. The seeds are now being distributed to other parts of India (Skerman, 1977).
In Sudan, it has also been used on a limited scale for sand dune stabilisation (National Academy 1980). In the hot blazing sun of the desert, the tree has been useful in providing shade and shelter (Pitman, 1961).

CHAPTER 7
GENERAL DISCUSSION

Acacia tortilis has continued to arouse interest among workers because of its variation and the future economical aspects it has in the arid lands of Africa and the Middle East.

The variation of *Acacia tortilis*, in habit, degree of indumentum on pods, petiole, peduncle and branchlets seem to be insufficient to distinguish the various subspecies. Yet, differences may exist with casual inspection of the trees and shrubs in the field. Other evidences besides morphology are necessary for further clarification on the differences of these subspecies. There is a possibility of ssp. *heterecantha* to be ssp *spirocarpa* var. *spirocarpa*, descending from East and Central Africa to South Africa. Timberlake in (1980) mentioned that ssp. *spirocarpa* occurs in the northern part of Botswana, and it occurs with ssp. *heterecantha* in Moreni area where they cannot easily be distinguished. However he said that ssp. *spirocarpa* has a more flattened crown and the pods are distinctively hairy and less coiled, yet he still emphasised that more fieldwork was needed to elucidate the differences in ecology.

Various workers who have dealt with ssp. *raddiana* in Egypt, Israel and Sudan (Andrews 1952, Fahn 1972, 1974 Tackholm 1974) consider it a species on grounds that it has a round crown with one stem red glabrous young branchlets, glabrous pods, and the tree branchlets are smoother than in other subspecies. The chromosome number of ssp. raddiana is different from other subspecies and its distribution is a bit isolated from the rest. It occupies habitats of severe climatic conditions especially across the Sahara where it diverges from the rest. The short recurved thorns are becoming rare on this subspecies while the long white slender forms are becoming more in number and longer than 6cms. Subspecies raddiana is distinct enough from others but it would be helpful if the anatomy, cytology, and chemistry of the rest of the subspecies is considered before drawing any conclusion of recognizing ssp. raddiana as a species.

Field work is necessary for further clarification and confirmation.

The local forms of subspecies spirocarpa var. spirocarpa may soon be a nuisance yet they cannot be ignored. They produce pods of various sizes, indumantum and pod surfaces. The seeds may also show variation.

While the taxonomist is looking for characters to use in clarifying the differences that exists in Acacia tortilis, the breeder is looking for characteristics of economic significance. The peculiarities of Acacia tortilis are being exploited for economic gain and research purposes. This is true especially where phytochemical aspects of Acacia tortilis and the seed beetle have showed that the level of amino acids in the seeds seem to influence the ability of the bruchid larvae to survive inside them (Southgate 1978). The chemistry of the seed is for taxonomy, entomology and economy. In arid lands where there is uncertainty in feed and food production, Acacia tortilis has been boosted high. It plays a dual role in the forage supply, serving both as a shade for grasses and as forage itself. It provides fixed nitrogen that benefits grasses and other ground level forages. It provides shade to the livestock, enabling them to graze during the heat of the day. It is a promising species for afforesting dry, rocky and sandy areas. Acacia tortilis provides wood for fuel, timber, wagon and dhow building and furniture for buildings. Gum and tannin are extracted from the species and many various uses which have been mentioned.

The type of woody plants like Acacia tortilis, tend to be ignored in areas of research and in the economy of a country on the whole, yet they have multi-purposes. The foliage of Acacia tortilis with grass provide animals with a variety of diet and help to maintain a balance in the vegetation. Because Acacia tortilis has proved useful economically, research should be done in areas of breeding to produce lines which are fast growing, thornless types and those with single trunks for wood production. Then some lines should be produced with branches which are low enough for browsing. Research in control of seed beetle attacks should be carried out. Germ plasm collection should be the first thing to be done and others would follow later. *Acacia tortilis* is disappearing at a quick rate in several areas especially East Africa because elephants destroy the trees when they eat the barks (National Academy 1979) and people cut the trees many times for various uses. Some protection measures should be considered. Breeding for better quality gum and yield should be considered while the same thing should be tried for tannin production.

Acacia tortilis will boost the arid land economy in the near future.

SUMMARY

There is a close morphological affinity in the subspecies of *Acacia tortilis* (Forsk.) Hayne. Although *Acacia tortilis* ssp. *heterecantha* and ssp. *spirocarpa* are more closely related, they can be narrowly distinguished by their pod surfaces. Ssp. *heterecantha* has pronounced ridges and microridges (on scanning), non-spreading hairs and globular structures on its pod surface; whereas ssp. *spirocarpa* has spreading hairs and non pronounced ridges on the surface of pods. However, chemical analysis of seeds, leaves and gum exudates, plus other taxonomic aspects besides morphology may clarify further differences.

Acacia tortilis. ssp. *raddiana* is distinct from the rest of the subspecies by being a tree with a round crown; it has glabrous pods and smooth dark red young branchlets. Cytologically, it is different from ssp. *heterecantha* and ssp. *spirocarpa*,anatomatically (wood sections), it is different from ssp. *tortilis*. In terms of chemical analysis for gum exudates, ssp. *raddiana* is related to all the subspecies. In distributional studies, ssp. *raddiana* occupies hotter regions and severe conditions than the rest of the subspecies.

For purposes of comparison and recognition of the subspecies, the taxonomic aspects which were under consideration for ssp. *raddiana* should be applied to the rest of the subspecies of *Acacia tortilis* and then field

Work should be carried out for all subspecies, for further elucidation of the differences in terms of ecology. Planting of ssp. raddiana in different environmental conditions would be necessary in order to see the effects on habit and other plant characters.

Research in breeding for high yield in pod production, for pest resistance, for high quality gum and tannin and for fodder would be of a future benefit to arid and semi arid regions in the economic aspects of the plant.

APPENDIX I

The herbarium Specimens used in Scanning

1.	Ssp. heterecantha	B.de Winter & Leistner	5881	22/5/57
2.	Ssp. raddiana var. raddiana	P.J Greenway	9444	4/11/57
3.	Ssp. raddiana var. pubescens	G. Aglmer	309	10/5/33
4.	Ssp. spirocarpa var. crinita	G.G.Trapnell	2156	19/8/51
5.	Ssp. spirocarpa var. crinita	P.J.Greenway	9961	3/4/61
6.	Ssp. tortilis	J.K.Jackson	4172	3/5/61
7.	Ssp. spirocarpa	M.Thulin and B. Mhoro	501	29/7/70

APPENDIX II

The herbarium specimens used in drawings

Specimen	Collector	Number	Date
Leaflets			
1. Ssp. heterecantha	Bella Vista	2632	26.11.70
	R.G. Strey	10294	26.11.70
2. Ssp. spirocarpa. var. crinita.	J.B. Newbould	5817	7.4.61
3. Ssp. spirocarpa	Bally and	14860	16.1.72
	A.R. Smith	14860	16.1.72
	C.A. Waterberh	2017	19.7.72
	W. Burger	3106	8.8.63
4. Ssp. raddiana var. raddiana	C.W. Mitchel	38	1966
	Senegal	-	—
	D.A. Ogden	-	3.8.59
	P.J. Greenway	9444	4.11.57
5. Ssp. tortilis	no collector's name	-	9.4.67
	M. Maldy	1244	1963
	R.M. Lawton	1976	8.3.78
	M. Alemayehu	1121	1976
6. Ssp. raddiana var. pubescens	Muriel	Type	6.11.1900
Pods			
1. Ssp. spirocarpa var.	J.B. Newbould	5817	7.4.61
	A. Peter	42674	
	E.Milne-Redhead & P. Taylor	11224	16.7.56

Specimen	Collector	No.	Date
2. Ssp. heterecantha	Wild & Drummond	7236	23.4.65
3. Ssp. tortilis	Pratt	75	1976
4. Ssp. raddiana var. raddiana	Gillet. J.B	23023	6.7.80
5. Ssp. raddiana var. raddiana	N.D Simpson	4447	14.11.27
6. Ssp. raddiana. var. pubescens	Muriel	Type	6.11.1900
7. Ssp. spirocarpa	H.F. Mooney	8254	23.12.59
	D.J. Pratt	-	3.1.66
	A. Bogdan	AB4091	24.8.50
	G.R. Gibbons	2585	1931
	D.J. Pratt	K559	

Seeds

1. Ssp. raddiana var. raddiana	J.D Kesby	30	19.8.60
2. Ssp. spirocarpa var. crinita	J.R.I. Wood	3090	23.11.79
3. Ssp. spirocarpa	J.W. Ash	306	8.3.70
4. Ssp. spirocarpa	S.R. Semsei	3963	16.9.65
5. Ssp. tortilis	Pratt	75	8.2.76
6. Ssp. raddiana var. pubescens	Muriel		
7. Ssp. heterecantha	B.de Winter & Leistner	5881	22.5.57

Specimen	Collector	Number	Date
Glands			
1. Ssp. heterecantha	J.H. Ross	3017	29.3.73
2. Ssp. heterecantha	B. de Winter & Leistner	5881	22.5.57
3. Ssp. heterecantha	Hanekom	2528	18.12.72
4. Ssp. tortilis	Alemayehu Haile	1121	1976
5. Ssp. spirocarpa	A.C. Troff	234	14.12.39

APPENDIX III

Herbarium specimens used for scatter diagrams

Name of a plant	Collector	Number	Date
1. Ssp. <u>spirocarpa</u> var. <u>crinita</u>	Greenway	442B	1956
	Bogdan	4091	24.8.30
	J.B. Newbould	325	20.4.58
	J.R. Wood	3248	22.5.80
	A. Peter	42674	13.7.26
	J.R. Wood	3090	23.11.79
	Tweedie	2299A	1.9.62
	Greenway	9961	1962
	T.B. Newbould	5817	7.4.61
2. Ssp. <u>heterecantha</u>	W.T. Hanekom	2528	18.12.72
	(B.de Winter (Leistner	5881	25.5.57
	Bella Vista	2632	26.11.70
	G. Strey	10294	26.11.70
	E.E. Galpin	9762	2.1.30
	(Harrismith	2829DD	19.3.70
	(G. Strey	9752	19.3.70
	Waterpoort	2229	8.1.74
	J.N. Pienaar	400	8.1.74
	J. Hutchinson	3003	21.2.29
	W. Hariekom	2077	26.1.73
	O.A Leistner	2643	24.8.61
	G. Strey	7999	31.1.68
	Ross.	1690	22.4.67
	E.E. Galpin	391	2.1.30
	Watmough	464	3.1.60

APPENDIX III

Herbarium specimens used for scatter diagrams

Name of a plant	Collector	Number	Date
1. Ssp. spirocarpa var.	Greenway	442B	1956
crinita	Bogdan	4091	24.8.30
	J.B. Newbould	325	20.4.58
	J.R. Wood	3248	22.5.80
	A. Peter	42674	13.7.26
	J.R. Wood	3090	23.11.79
	Tweedie	2299A	1.9.62
	Greenway	9961	1962
	T.B. Newbould	5817	7.4.61
2. Ssp. heterecantha	W.T. Hanekom	2528	18.12.72
	(B.de Winter (Leistner	5881	25.5.57
	Bella Vista	2632	26.11.70
	G. Strey	10294	26.11.70
	E.E. Galpin	9762	2.1.30
	(Harrismith	2829DD	19.3.70
	(G. Strey	9752	19.3.70
	Waterpoort	2229	8.1.74
	J.N. Pienaar	400	8.1.74
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	W. Hariekom	2077	26.1.73
	O.A Leistner	2643	24.8.61
	G. Strey	7999	31.1.68
	Ross	1690	22.4.67
	E.E. Galpin	391	2.1.30
	Watmough	464	3.1.60

Specimen	Collector	Number	Date
Ssp. heterecantha	H.G. Schweickerdi	1699	17.12.81
	R. Seydel	3132	3.5.62
	Wild and Drummond	7236	23.3.65
	Liebenberg	4751	1949
	B. de winter	2719	14.3.55
	R.S. Giess	1993	9.3.58
	J. Wiss	948	1948
3. Ssp. tortilis	M. Malidy	1244	1963
	F.N. Hepper	5719	14.10.75
	R.M. Lawton	1976	8.3.78
	F. Meyers	3194	16.6.60
	Popov, Jillin, Gilliland	4282	14.3.52
	Pratt	75	8.2.76
	L. Birdwood	179	-
	Radcliffe-Smith	5406	8.10.77
	E.R. Guest	-	21.7.52
	Collenethe	1948	4.3.80
4. Ssp. spirocarpa. var. spirocarpa	B. Matthew	6761	11.6.70
	Leippent	5269	31.10.64
	Pratt	-	3.1.65
	Headley	326	14.8.68
	Greenway	-	14.8.68
	Dogget	112	6.7.49
	Michelmore	728	-
	S.P. Kibuwa	2485	15.8.76
	W. Brger	3471	24.4.64
	A.C. Trott	-	14.2.39
	Waterberg	2017	19.7.72
	D. Herkaker	274	9.2.66
	J.B. Gillet	5260	1.3.33

Appendix III cont.

Specimen	Collector	Number	Date
4. Ssp. spirocarpa var.	J. Knight	-	9.12.65
spirocarpa	H.M. Richards	25674	-
5. Ssp. raddiana var.	G. Wasingham	33	31.1.17
raddiana	S. Collenette	58	10.3.77
	J.B. Gillet	-	6.7.80
	Tackholm	172	1963
	G.F. Grasorbk	1	25.12.34
	P.H. Dario	3797	4.8.41
	J.E. Dinsmore	3194	16.6.10
	H.F. Mooney	-	1952
	J.D. Kesby	30	19.8.60
	M.D. Simpson	4447	14.11.27
	Khattos	6215	4.3.28
	J.R. Shasetai	1406	3.11.33
	D.G Schweinifurth	1985	1865
	D.G.Schweinifurth	44	1877
	W.B.K Shaw	19	31.10.30
	D.A. Ogden	-	3.8.59
	D.F. Clements	194	26.8.62
	R.N. Kaul	-	-

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subsp. Raddiana (Savi) Br...
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