Varietal differences amongst sorghum crop residues in relation to their phenolic HPLC-fingerprints and responses to different environments

I Mueller-Harvey*[1] and M S Dhanoa

AFRC Institute of Grassland and Environmental Research, Hurley, Maidenhead, Berks. SL6 5LR, UK

(Received 30 January 1991; accepted)

ABSTRACT

Phenolic compounds in leaves and stems from different sorghum varieties grown at several sites were analyzed by HPLC. The chromatograms were subjected to cluster analysis. Environment had greater effects on phenolic composition than variety However, some differences were also due to varietal effects. Whilst most varieties seemed to give strong environment x genotype interactions, the phenolic compositions of two bird-resistant (BR) varieties were more stable in different environments. Differences between bird- and non bird-resistant varieties were clearly expressed in leaf phenolics at some but not all sites. All varieties had similar stem phenolics.

This type of information is relevant to breeding programmes. A strategy is suggested for selecting BR-varieties with improved digestibilities.

---

[1]*Present address: AFRC Institute of Food Research, Shinfield, Reading RG2 9AT, England

Key words: HPLC fingerprints, polyphenolics, red pigments, cluster analysis, sorghum varieties, bird resistance, genotype x environment interactions, plant breeding.

INTRODUCTION

Sorghum is one of the most important cereals in the semi-arid tropics and subtropics. It is a dual purpose crop. The grain is used for human consumption and the crop residue used as ruminant feed. Crop residues such as sorghum are an important feed resource for ruminants in developing countries with agricultural systems based on smallholder cereal production. Intensive breeding programmes have resulted in increased sorghum grain yields but little attention has been paid to breeding for the nutritional quality of the crop residue. Yet livestock form a valuable and often vital component of the farming systems in developing countries. In some instances the value of livestock products derived through the use of crop residues exceeds that of grain for human consumption.

Much research has been devoted to upgrading straw through various chemical treatments (Jackson 1978), but little attention has been given to natural variation in the nutritive value of untreated crop residues. Recent work at the International Livestock Centre for Africa has shown a range of over 20 units in _in vitro_ digestibility of crop residues among different varieties of sorghum (Reed _et al_ 1988). A similar range has been reported among varieties of barley (Lufadeju _et al_ 1985). Feeding trials have shown significant differences in nitrogen digestibility among crop residues from bird resistant (BR) and non bird resistant (NBR) sorghum varieties (Aboud _et al_ 1990). Within the context of small

farms it is more desirable to identify varieties with inherently higher digestibilities than to use expensive and hazardous chemicals to improve digestibility.

Recent work by Reed et al (1988) has shown that soluble phenolic compounds in sorghum are negatively correlated with digestibility. These authors also found that phenolic contents were significantly different between varieties (Reed et al 1987). In addition to varietal effects, environmental effects on the nutritive value of crop residues appear to be of considerable importance (Reed et al 1988).

Sorghum is well known for its ability to synthesise many different phenolic compounds in large quantities (Butler 1987, 1989) compared to other cereals. There is good evidence suggesting that phenolics of different varieties vary both qualitatively and quantitatively. An example of a qualitative difference is that the tannins which occur in BR sorghum grain not occur in NBR grain. There are also quantitative differences between BR- and NBR-varieties, for example the leaves of BR-varieties contain more red pigments than leaves of NBR-varieties (Reed et al 1987, 1988)

In the last few decades, chemotaxonomy has made extensive use of phenolic compounds to differentiate amongst plant species (Harborne 1975). More recently, a small group of phenolics has been used to identify various cultivars within the same species, i.e. flower flavonoids in Azalea cultivars (Van Sumere et al 1985). These authors employed high performance liquid chromatography (HPLC) to obtain cultivar specific 'fingerprints'. HPLC is well suited to such taxonomic purposes

i h i prod qu i ti ta d hi h d
imi i tai h gh rph l i y ems
M q ch q i i HPLC d be ub
ta i i y i McRa et al) d Miy hita et
) h pe med pon d p t
ogni i LC d ta de d ibe
p t di ppl i d amo g t
b di

im h d i i wh h LC
i i i ombi i h p ecog ion an y i
d be ed dy h i l i g h h i
ompo i i id 4 hum i
i p i i h BR i
d h i rma i b l d
t b de h i i
i h mp ed id di tibili i

MATERIALS AND METHOD

Ma i

h op i mp h ed ty
obt i d h i Li k
A i A i Ab hiopi wo ma hed i l
i d ed Me k i h i t l y i
b i i i l A nd C Tw
h hed i ed M k Duk
i m) t i B d D l i
omp y mi d b k d i d h h
i ti R pe ommu T p id
i i th i

Methods

T nd f rqh mp

i pa ed i
b ad LB l h th LS and tem ST acti Th
i -d ied a pa i deci ed
b l h ep i lows bec h of
ime eq i ed h HPLC and bec Reed et al
emo ted pe h d
h ari i i i i Eq amount h of
h pli he bu ed d h h
i Th ked h amp mq ed i
tone/ te (/ ml 1°C mi i
i ba h h h y mi ed nd hen i ed
l i y he i he t t i ged
and th supe li d i ed th ou h
p t i ai i woo Th w d
p t ml i ceton / An iquot (µl
i ted i t th HPLC y i Rheody l i h
mi

HPLC ndi on

A pa ed i h µ Bon pak C
M po /W W d UK ined 1°C
column bl k hea Ch oq ph Hengoed U
p ed by column i pel i
ODS Wh tman Maidstone UK W te id 7
l A h R hbu C mi W bu
Sc t and R ed adi ti
l min T i ear di arted A and nded
i h t G adi M
C aMet nd pump (LDC Mi Roy St UK) A

ph odiod ay d te M llip /W) ed
rd pe be wee d

s is l/ thema i y i
HPLC hroma og t d i h W t
p kage (Mi i /W) Al h omat ams
hi i ed h mp h ped b in Th i i poi t
d limi thi hump (Fi) A
pe k umbe ed th i peak h i ht d rnined
Th HPLC i hts wer ly ed by i q linka
l i di t Gow R ( )
GEN TAT (th hod y amp l
qeth i th i i di betwe h i h
l Th proces i ti ed ll ampl d
l i all l Th
l i h p i hi nd betw pr ed i
mi pa (MS A MST i h t rk
h rt l h ing ll pl (Go d R
F dy MST i i po ib in
i l i h p amon i i d d i y th
i h ph l ncen ti qh id

RESULTS

lan p rts

Th ph li compo iti d t di ed between
th h p p i yi lded d
g PLC h omat ams m f h d LB)
h h L T i

Le bl
Cl g f ph rh g 0

Withi h B- i i g Deb
i h imil h i omp i i hown by th it
Th ob i mad j
k D- i ( )
M it A) i di h g
l sma A B l t ed (i) Th
t th ome h t i
LB h i t i wh th it
i tal onditi importa

F amp LB i ty / h ly ed
ph i i qe i i h i (Me k A!
d De i [t A B d i d
A! Duk howe th X/ (LB-pe h h h
be) y k h i i whi h
ph ompo i t ib t
(Fi A i hbo C i ly
ed A B h h h C Fi
LB- h i h ed
1 / / / d F: id l did t l
indi i h t th h i ompo iti h
ed by i nme th by y

and NBR h ome t LB ph i RR
NBR ga l t Deb it wh
Me y h N R i i l ed F th rmo th
l h ed th ry iqi h
i i examp h opi A B C D)
U (4 D i hi d di t h
ence l ndr (J L od pe commun

Th da ide ome p imi y idence h ph i
y h i i i h i abl i eave examp
S (A C d ES P 1 (A C imil nd
i i y i hey l t ighbo bo
Me nd De ei Fi A A and C C1 pai Fi
4 edo nd D / /1/ ed by i
pedi Tab d th i i th Deb i
i ed (C Howe h ame i i
Me (tr A di l ter Se A2 C whi i
Dobb (Tab red wi h Dobb (B
Me k

Phe li abso b ng Onm
Le bl i ed h p es pigmen
ab rbin t to h piqmen
be) i tr d eme qed between BR nd N
i i

Le f sh ths
C g ph i ab rbi g 2 0 m
it ect qui ked ith h th ph li
Di i rme Me k ial A am d
Deb i sampl (i) The LS-ph li om he econd
M k l ( ) i i h ubg p Fig

h th h i BR i l ed t y om
h N R i i Me ka (ial A) (Howe
h t ed i t Deb it (i y yi ded
NBR nd BR l i hows the LC
h L ph i nd i i
t Melka BR LS h oma og ams xhibi ed tr pe k

umb ed whil NBR LS hroma og ams nded
g pe k umbe ed 4 d/

ti rmed l l t ed th i
f i i d B8 D7 di
) R nd ( ) l (i) V i E
P A9 nd A wh h imi pedi (Tab
h d imil LS h i ompo i i Thi
i te by peak whi h w ly p th
ch omatog (i) Me k ampl ed d
D / / / (A2 4 p l t ed og h They
l th gh h i ry i i pe i BR
g th i be ed wh ch h
impo Deb i (i
h di betw h i LS ph i ompo i)

C i f *ph* *b* *b*
C ed h h ph l hi h ab b
b h ab t by h ame ird i d
th ed l t i LS-p i ab bi
Howe i tr t h UV- ab bing phe i
i impo t th i Th i th w
ti i ba ed NBR i
thin th up i ed i
Chr og ams LS R ded t
early di th NBR i i (F

St

On y h UV- ab i ph l i ti ed i
ems th igme i omp i ly

l i h h ect ph i (i
ddi i h ome mal i i q
tri qi hiop A Uq d (
) d B d d/
BR (A. C d
A C 1 C 1 pe i y)

h i po i th i i own di.
it l y ems h i. LB LS F
p ems kiny ka g own Melka d Duk
p od ed i i HPLC i. pri (i B D) Thi
pp i id (A) d ES P (A C) ph l
Mel d Deb i F)
C pe i lec ed by imi. i i. in
ph i amp d (A. A. C C)
d d / / / (A. A) ph l
p t embled h Fig)

D SCUS ION

Thi t d be h ppli ti i l ka ge l
y i t l ti y l PLC h omatog
t rp h h eby been d h
i l i g ph l. orpo: i i gh id Thi
i be p b ed i h i: h
i th iπ ed i ibi i y arti
t i h be pai h po b i y i. i i hi
BR NBR i Th i. nmen l
i i O ome h t ome i i ary id
ob ed h h i h ph
comp i

HPLC-fingerprints of extractable phenolics differed greatly between the three plant fractions, leaf blade, sheath and stem (Figs 2, 5, 9). It is therefore desirable to analyze plant fractions separately when investigating phenolic composition in relation to digestibility. Generally speaking, the smallest varietal differences were found amongst stem phenolics, and the largest amongst leaf sheath phenolics. Leaves are the most nutritionally valuable fraction of the residues because of their high N-content and intake. Therefore a better understanding of the factors influencing leaf phenolic composition will assist the development of cultivars with improved nutritive value.

Several factors affected phenolic composition of sorghum residues. In addition to the effects of varieties, environment also strongly influenced phenolic composition. In general, environmental effects were very strong on LS-phenolics but not on LB- and ST-phenolics (Figs 2, 5, 9). This means that gene expression of phenolic synthesis is apparently differently affected by environment in the three plant fractions.

Variety ESIP 21 is a good example to illustrate these points. Its LB-phenolics were distinctly different from those of other varieties (compare Figs 3 and 4). When this variety was grown at different sites (trial A and C) the LB phenolic fingerprints were similar (Fig 10a). However, its LS-phenolics - whilst also being different from other varieties - were strongly affected by environment (Fig 10b).

qr pi HPLC i qerpri t ba ed h i
imi i i by i li ka l y i led h
it i po i l i i i h NBR i i by
ly h ir he h LS BR arie i ha
di in i of peak i HPLC hroma og ecorded 4
ig) O d/ pe ks (umbered nd 4
ed h i h LS he i rp i NBR
i i ecorded (Fi)

Thi y h l demo t ed th h i rom di
h ype ed di y by i
omposi i ew i ti wa i l tab LB
LS ph li f / 4 and LB and ST phenol f
ki aru ed by i h hos of h
i (i 3 Th type me
i bec i h i l ended t h igh in
vitro di ibi i i ed th vari i J D Reed
pe commu) ii) th i i bi d i t

Ge ype i i te ct i pos cha
p eede d ha bee hown i lue chemi
i h p t i t i h
g i i yi i nd in vitro di ib i y i
ba y w d timo hy Saeed et al Smi h and Smi h
98 Ka nd Go Wri h and Hu h 1 McE oy
d h i 1) hum g type i h i y bl
ph i ompo i d di ibility onme
ed be id i ed be ecommenda i ubsi
f rme he mad i i the iti
i i l i bo h imp ed
yi l d j d i h h i l

purpos op ed for in nd odde Cappe et al
h ed h hi h y l nd i ed iqes ibi ity y
no be mu y l i

l ed demonst ted h i
y he i ed p qment i l we expr ed much mor
ome i e Mel th h Duk
Debr i) addi i h qe piqmenta ions wa
te depend A Duk to l i concentr i
h i i ompar ti y gen type A
Me k phen li concen ch hi her
i i i i occu ed amon th ame
ype Th i piqme t i i gh l
and been ummari ed by Doh ty et al

F th de opment iti i i esearch i
eeded de rmi whi h i onme l to i
piqme i i h id Li i mos
import t l t t llii l onoid ynthesi
piqme i i i d th t (R hi et al
1 R qe nd Ko d nd nces th in
Howe i d emper t equ ry i l nce
R hi et al A empe ur di ed
iqni i y amon h udy i i Me k i
i V l ey bei h h pl (Reed et al As th
i l di ed i l tud ligh i i y migh be
e too i additi ther act h
te i i d pe t i d Mu H y

Breedi tr egy toward BR i with improved
dige t bil y

i i Dukam h i ld th ph li

y ced by ir ede

ann ph i y i th i i i l i

di ib i y h id i ike Me k

eb t wh ph l i th i d

i al di ibi i i eed et al

i i i t imp oveme i l p

id be obtai ed di i i

type ype wh ph i

i l ti y ed y ironme t l

h tab ype pe i y impo

th it wh th i id i d damag high d

th BR ti l i d i ab h

t b type ted bec BR i i d t

h h h ph i h BR i i d

th dy h hown h be ly

d by ironment pa i ly i i i

h ecomm d h ly t y

ed igme i h th i th l (1

/ d bed R et al ([h pti

t h d h be ded nu hi h i

th l h wi h maximum abs i th ed pigme

(npubl hed ts h h t iqi y

d bed] d t d i h di

p gm d R d N R

i Wh h d h d d i ll

h h i pigme y th i

amon BR l by h l

th ynth i t y On y l i ly abl
ti h d be ted imp ed di ibi i i

ACKNOWLEDGEMENTS

W i h nk P R ed th U i ity f
Wi con i Madi USA (rme ly t he erna i
Li t Centr or Af i (LCA) Add Ababa Eth opi
d Kebede ti t Aq i R earch N
h pi th h ampl nd kn edge th ir hi y
ed i tance We indebted Mr P M Bl kwe
i p tience and kil i per i h HPLC an ly i We
th k LCA idi i i i nd oqi i po t
A McAl pport and ti al comments hi hly
appreciated

Thi h t umb EMC nded by h
Ov De l pme Admi i i So gh ampl we
impo ted nder licence umbe PHF i ued by th
Mi try Ag i l 'i h i and ood

Legend to Figures:

Figure 1: Cluster analysis using HPLC-peak heights at 280 nm of phenolics extracted from leaf blades (LB), leaf sheaths (LS) and stems (ST) of 24 sorghum varieties grown at several sites. The letters denote sites, the numbers denote varietal entries (see Table 1).

Figure 2: Cluster analysis using HPLC-peak heights of leaf blade phenolics from several sorghum varieties which absorb at 280 nm (see Fig 1 for lettering).

Figure 3: Phenolic HPLC fingerprints of leaf blades from (a) X/35:24 and (b) Ikinyaruka grown at Melkasa (sites A and B), Debre Zeit (site C) and Dukam (site D).

Figure 4: HPLC-separations of leaf blade phenolics from two varieties with similar pedigrees (ESIP13 and ESIP21) grown at Melkasa.

Figure 5: Cluster analysis using HPLC-peak heights of leaf sheath phenolics from several sorghum varieties which absorb at 280 nm (see Fig 1 for lettering).

Figure 6: HPLC-separations of leaf sheath phenolics recorded at 280 nm from a) six bird resistant and b) six non bird resistant varieties grown at Melkasa.

Figure 7: Cluster analysis using HPLC-peak heights of phenolics absorbing at 490 nm from leaf sheaths of 24 sorghum varieties (see Fig 1 for lettering).

Figure 8: HPLC-separations of leaf sheath phenolics recorded at 490 nm from a) six bird resistant and b) six non bird resistant varieties grown at Melkasa.

Figure 9: Cluster analysis using HPLC-peak heights of stem phenolics from several varieties which absorb at 280 nm (see Fig 1 for lettering).

Figure 10: HPLC-separations of (a) leaf blade- and (b) leaf sheath-phenolics from ESIP 21 grown at Melkasa and Debre Zeit.

Table 1a:

Description of sorghum varieties grown at sites A (Melkasa) and C (Debre Zeit).

Designation	Entry no.	Pedigree	Country of origin	Resist-ance
Ikinyaruka	1	Ikinyaruka	Rwanda	BR*
Serena	2	P127 x Dobbs	Uganda	BR
Seredo	3	(Serena x CK60)	Uganda	BR
5D x 135/13/1/31	4	Seredo	Uganda	BR
X/35:24	5	X/35:24	Sudan	BR
Framida	6	Framida	West Africa	BR
ESIP4	7	(NES821 x Awash1050) x NES9435	Ethiopia	NBR**
ESIP7	8	Kobomash76 x NES8835	Ethiopia	
ESIP13	9	$76T_4$#432 x $76T_4$#478		
ESIP17	10	$76T_2$#3 x NES8922		
ESIP21	11	$76T_4$#432-1/269 x $76T_4$#478		
ESIP25	12	$76T_4$#441 x NES8835		
ESIP40	13	(FLR101 x CS-3541)-1-1-2	Sudan	
ESIP43	14	((SC-432 x CS-3541) x E-35-1)-2	Sudan/ Ethiopia	

* BR = bird resistant variety
** NBR = non bird resistant variety

Table 1b:

Description of sorghum varieties grown at sites B (Melkasa) and D (Dukam).

Designation	Entry number	Pedigree	Country of origin	Resist-ance
Ikinyaruka	1	Ikinyaruka	Rwanda	BR*
Susa	2	Susa	Rwanda	BR
Seredo	3	(Serena3 x CK60)	Uganda	BR
5Dx135/13/1/31	4	Seredo	Uganda	BR
X/35:24	5	X/35:24	Sudan	BR
Framida	6	Framida	West Africa	BR
5DX160	7	5DX160	Uganda	BR
E525HT	8	E525HT	Uganda	BR
3KX72-1	9	3KX72-1	Uganda	BR
SVR8	10	SVR8	Burundi	BR
Dobbs	11	Dobbs	Uganda	BR
MW5020	12	-	-	BR
SVR157	13	SVR157	Burundi	BR
E1291	14	E1291	Ethiopia	BR
Gambella1107	15	Gambella1107	Ethiopia	NBR**

* BR = bird resistant variety
** NBR = non-bird resistant variety

REFERENCES

Aboud A A O, Reed J D, Owen E, McAllan A 1990 Feeding sorghum stover to Ethiopian sheep: effect of stover variety and amounts offered on growth, intake and selection. *Animal Prod* (in press).

Butler L G 1988 The role of polyphenols in the utilization of ICRISAT-mandated grain crops and applications of biotechnology for improved utilization. Biotechnology in tropical crop improvement: *Proc Int Biotechnology Workshop*, 12-15 Jan 1987, International Crops Research Institute for the Semi-Arid Tropics, Patancheru, A.P. 502 324, India. pp. 147-152.

Butler L G 1989 Sorghum Polyphenols. Chapter 5 in: *Toxicants of Plant Origin. IV. Phenolics*, ed Cheeke P R. CRC Press, Inc., Boca Raton, Florida, pp.95-121.

Capper B S, Thomson E F, Rihawi S 1989 Voluntary intake and digestibility of barley straw as influenced by variety and supplementation with either barley grain or cottonseed cake. *Anim Feed Sci Technol* **26** 105-118.

Doherty C A, Waniska R D, Rooney L W, Earp C F, Poe J H 1987 Free phenolic compounds and tannins in sorghum caryopsis and glumes during development. *Cereal Chem* **64** 42-46.

GENSTAT 5 Reference Manual 1987 Clarendon Press, Oxford.

Gower J C, Ross G J S 1969 Minimum spanning trees and single linkage cluster analysis. *Appl Statistics* **18** 54-64.

Harborne J B 1975 Biochemical Systematics of Flavonoids. In: *The Flavonoids*, eds Harborne J B, Mabry T J and Mabry H, Part 2. Academic Press, New York, pp.1056-1095.

Jackson M G 1978 Treating straw for animal feeding. *FAO Animal Production and Health Paper 10*. Food and Agricultural Organization of the United Nations, Rome.

Kang M S, Gorman D P 1989 Genotype x environment interaction in maize. *Agron J* **81** 662-664.

Lufadeju E A, Blackett, G A, Orskov E R 1985 The effect of variety of spring barley straw and ammonia treatment on nutritive value. *Proceedings of the Nutrition Society*, Abstracts of Communications, 409th Meeting of the Nutrition Society, 21-22 March 1985.

McElroy A R, Christie B R 1986 Genotype x environment interactions for <u>in vitro</u> digestibility of timothy (<u>Phleum pratense</u> L.) genotypes. *Can J Plant Sci* **66** 315-321.

McRae K B, Lidster P D, DeMarco A C, Dick A J 1990 Comparison of the polyphenol profiles of apple fruit cultivars by correspondence analysis. *J Sci Food Agric* **50** 329-342.

Miyashita Y, Ishikawa M, Sasaki S-i 1989 Classification of brandies by pattern recognition of chemical data. *J Sci Food Agric* **49** 325-333.

Morgan A G 1989 Chromatographic applications in cultivar identification. *Plant Varieties Seeds* **2** 35-44.

Mueller-Harvey I 1989 Identification and importance of polyphenolic compounds in crop residues. In: *Physico-chemical characterisation of plant residues for industrial and feed use*, eds Chesson A and Orskov E R, Elsevier Applied Science, London. pp. 88-109.

Racchi M L, Mikerezi I, Gerats A G M, Gavazzi G A 1985 Effect of S_n on activity of phenylalanine ammonia-lyase and UDP-glucose: 3-O glucosyltransferase in maize seedlings. *Genetics Agraria* **39** 338.

Reed J D, Tedla A, Kebede Y 1987 Phenolics, fibre and fibre digestibility in the crop residue from bird resistant and non-bird resistant sorghum varieties. *J Sci Food Agric* **39** 113-121.

Reed J D, Kebede Y, Fussell L K 1988 Factors affecting the nutritive value of sorghum and millet crop residues. In: *Plant breeding and the nutritive value of crop residues*, eds Reed J R, Capper B S & Neate P J H, Proceedings of a workshop held at the International Livestock Centre for Africa, Addis Ababa, Ethiopia, 7-10 December 1987. pp. 233-251.

Rengel A, Kordan H A 1988 Photosensitivity of anthocyanin production in dark-grown and light-pretreated Zea mays seedlings. *Can J Bot* **66** 1021-1027.

Saeed M, Francis C A, Rajewski J F, Maranville J W 1987 Genotype x environment interaction and stability analysis of protein and oil in grain sorghum. *Crop Sci* **27** 167-171.

Smith J S C, Smith O S 1986 Environmental effects on zein chromatograms of maize inbred lines revealed by reversed phase high-performance liquid chromatography. *Theor Appl Genet* **71**, 607-612.

Van Sumere C F, Vande Casteele K, De Loose R, Heursel J 1985 Reversed phase-HPLC analysis of flavonoids and the biochemical identification of cultivars of evergreen Azalea. In: *The Biochemistry of Plant Phenolics*, eds Van Sumere C F & Lea P J. *Annual Proceedings of the Phytochemical Society of Europe* **25** 17-43.

Wright D, Hughes L G 1989 The effects of site and variety on the in vitro digestibility of spring barley straw. *Plants Varieties Seeds* **2** 117-124.

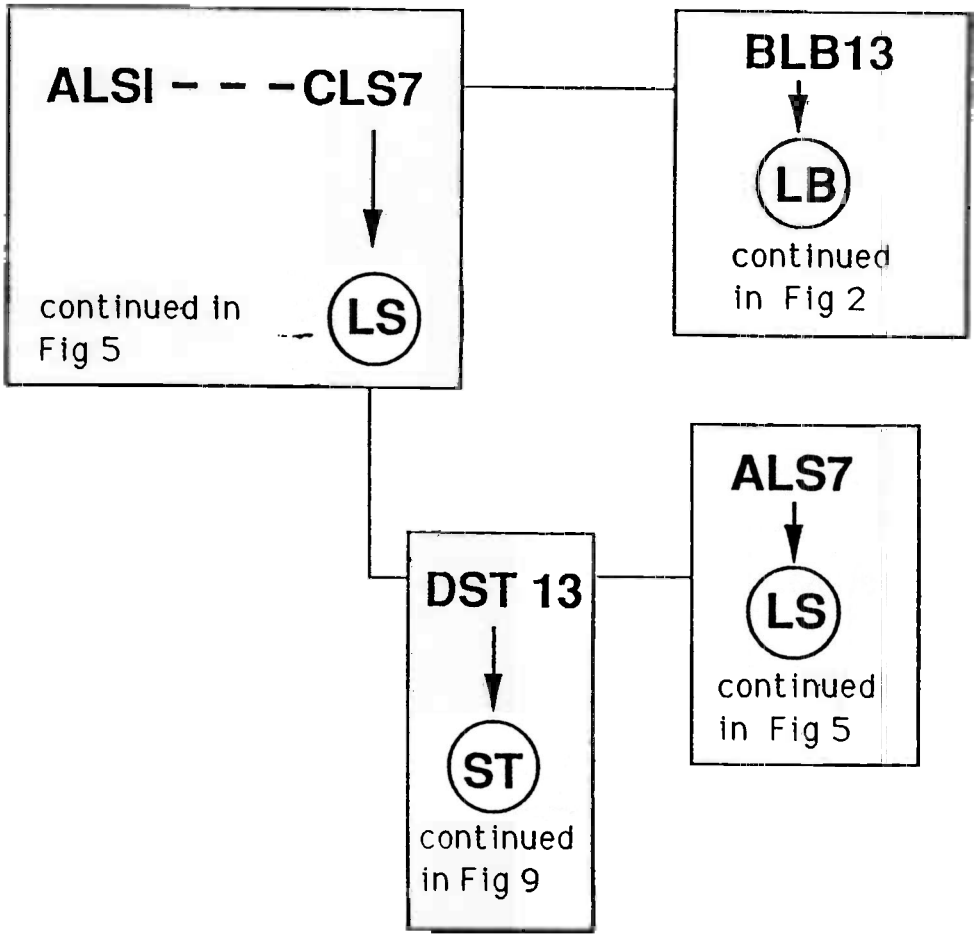

ALSI - - -CLS7
continued in Fig 5
LS
BLB13
LB
continued in Fig 2
ALS7
LS
continued in Fig 5
DST 13
ST
continued in Fig 9

Fig 1

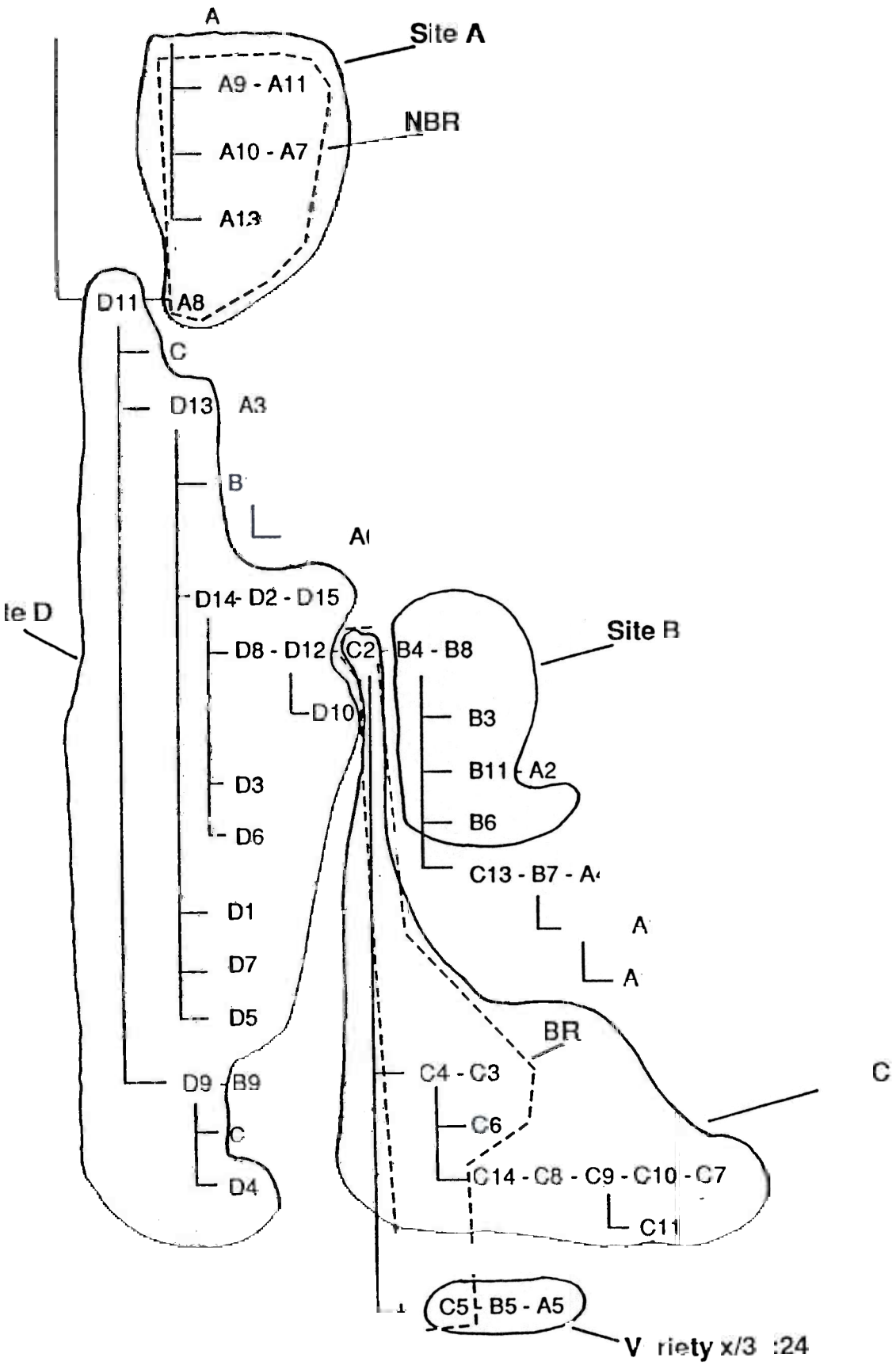

A
Site A
A9 - A11
NBR
A10 - A7
A13
D11
A8
C
D13
A3
B
D14 - D2 - D15
te D
Site B
D8 - D12
C2
B4 - B8
D10
B3
B11 - A2
D3
B6
D6
C13 - B7 - A
D1
A
D7
A
D5
BR
C
D9 - B9
C4 - C3
C
C6
D4
C14 - C8 - C9 - C10 - C7
C11
C5 - B5 - A5
V riety x/3 :24

Fig 2

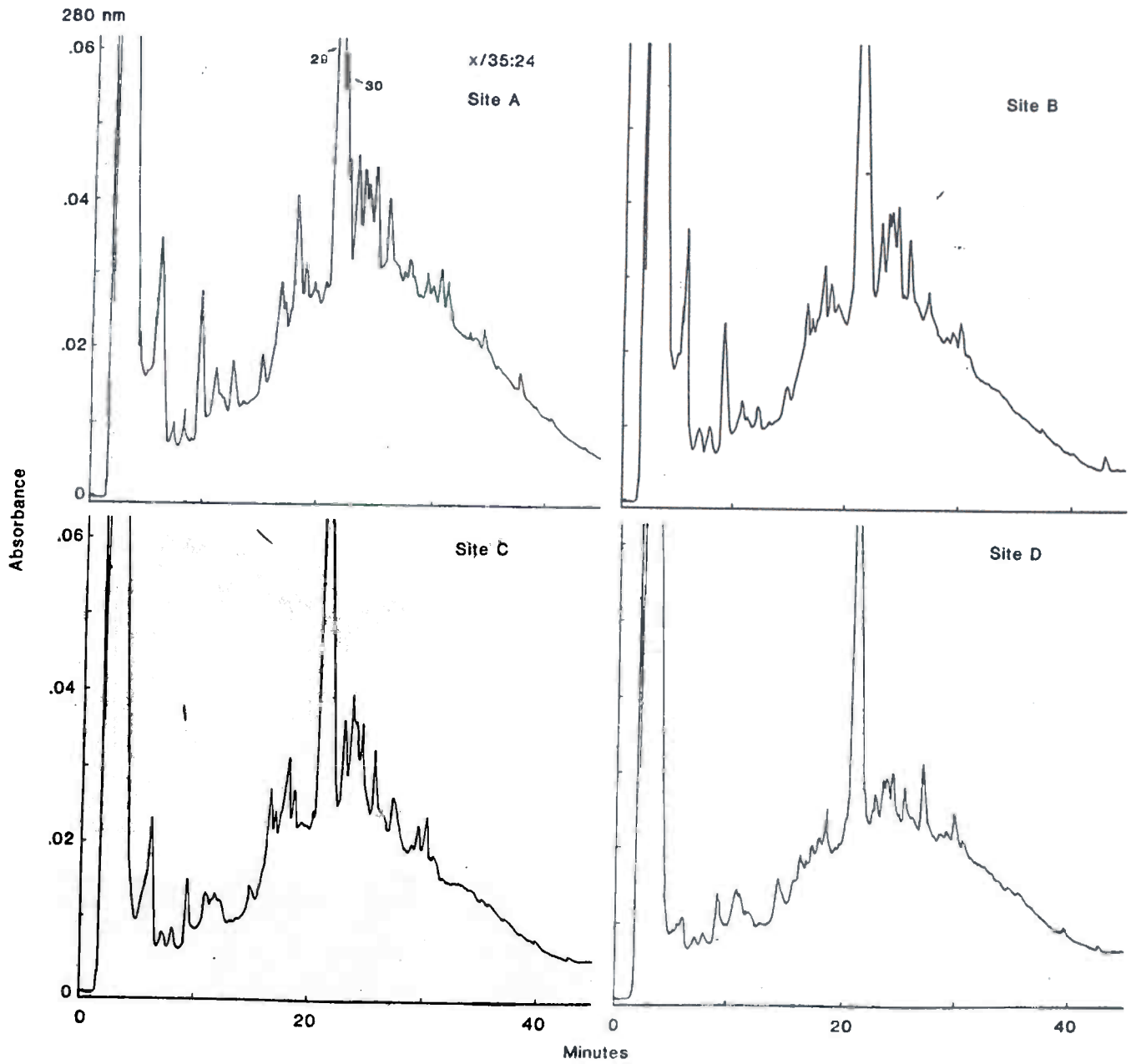

280 nm
.06
.04
.02
0
29
30
x/35:24
Site A
Site B
Site C
Site D
Absorbance
0
20
40
Minutes

Fig 3a

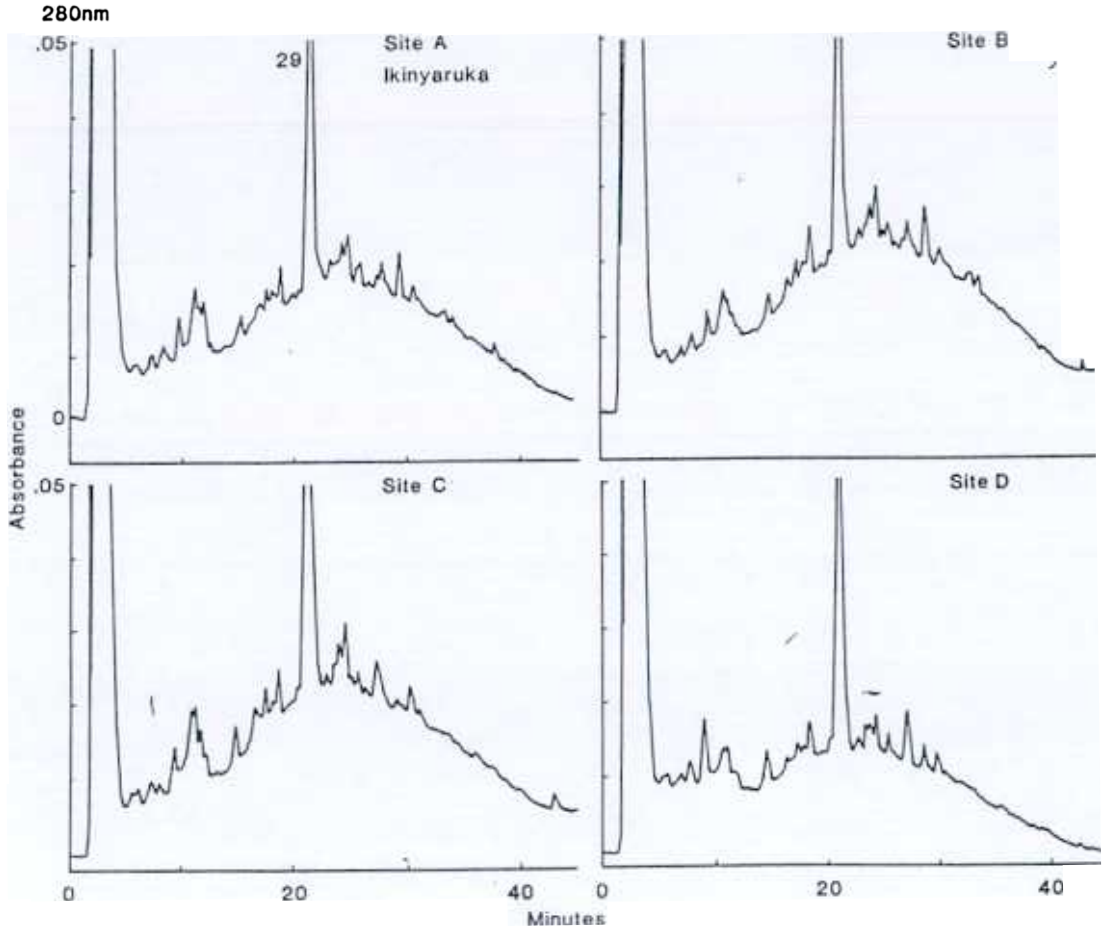
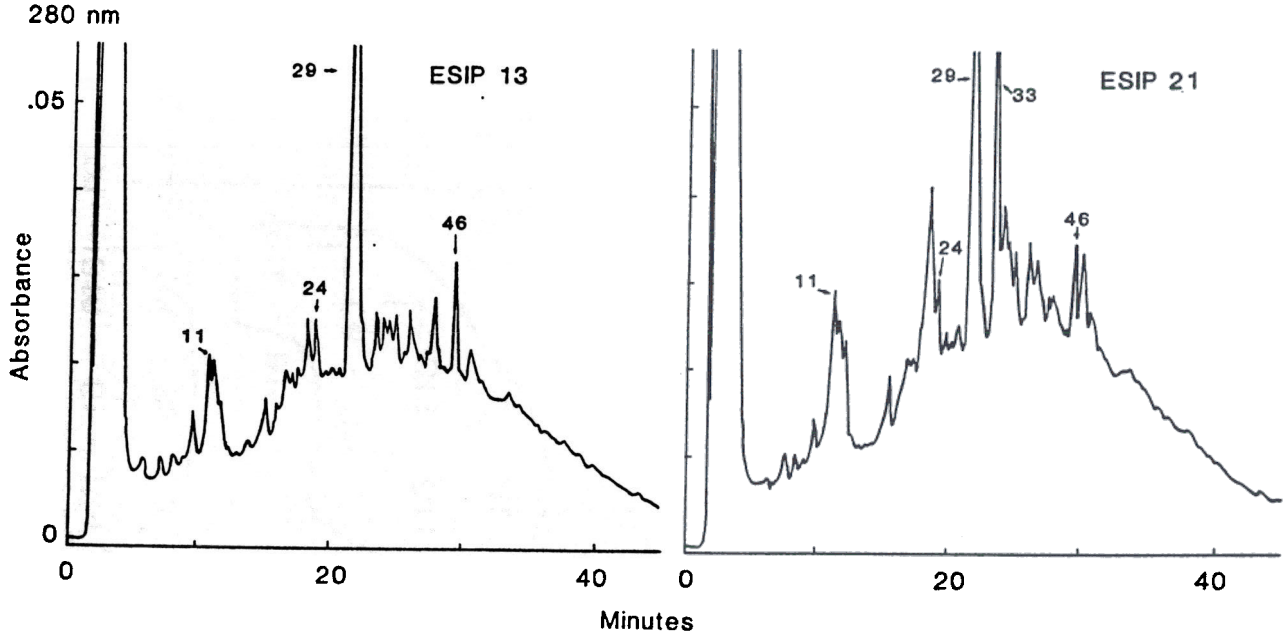

280nm
.05
0
Site A
Ikinyaruka
29
Site B
Site C
Site D
Absorbance
0
20
40
Minutes

Fig 36

Fig 4.


280 nm
.05
0
Absorbance
ESIP 13
29
11
24
46
0
20
40
ESIP 21
29
33
11
24
46
0
20
40
Minutes

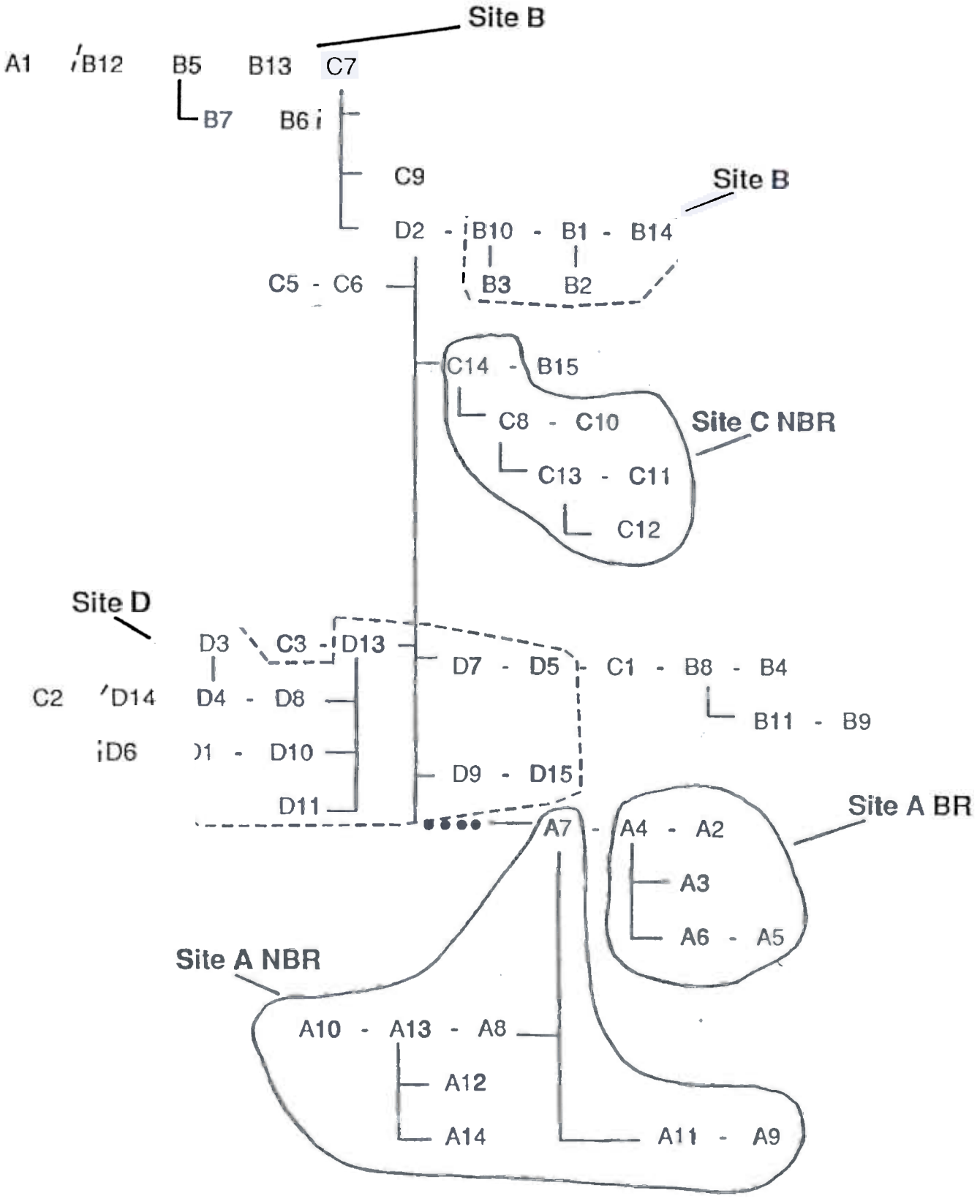

Site B
A1
B12
B5
B13
C7
B7
B6
C9
Site B
D2 - B10 - B1 - B14
C5 - C6
B3
B2
C14 - B15
C8 - C10
Site C NBR
C13 - C11
C12
Site D
D3
C3 - D13
D7 - D5 - C1 - B8 - B4
C2
D14
D4 - D8
B11 - B9
D6
D1 - D10
D9 - D15
D11
A7 - A4 - A2
Site A BR
A3
A6 - A5
Site A NBR
A10 - A13 - A8
A12
A14
A11 - A9

Fig 3

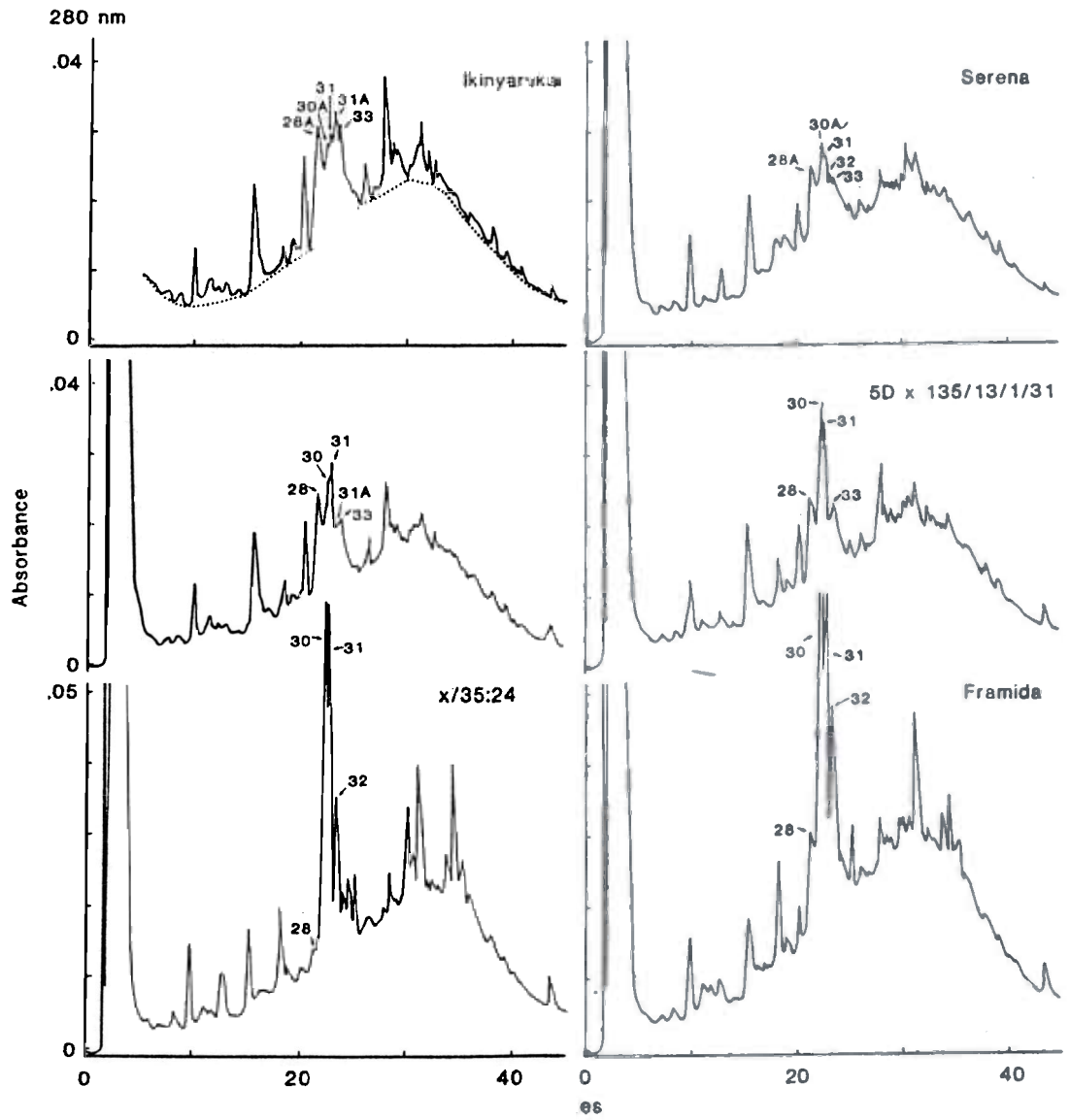

280 nm
.04
0
Ikinyarwka
31
30A
31A
28A
33
Serena
30A
31
28A
32
33
Absorbance
.04
0
30
31
28
31A
33
30
31
5D x 135/13/1/31
30
31
28
33
.05
0
x/35:24
32
28
30
31
Framida
32
28
0
20
40
0
20
40
es

Fig 6a

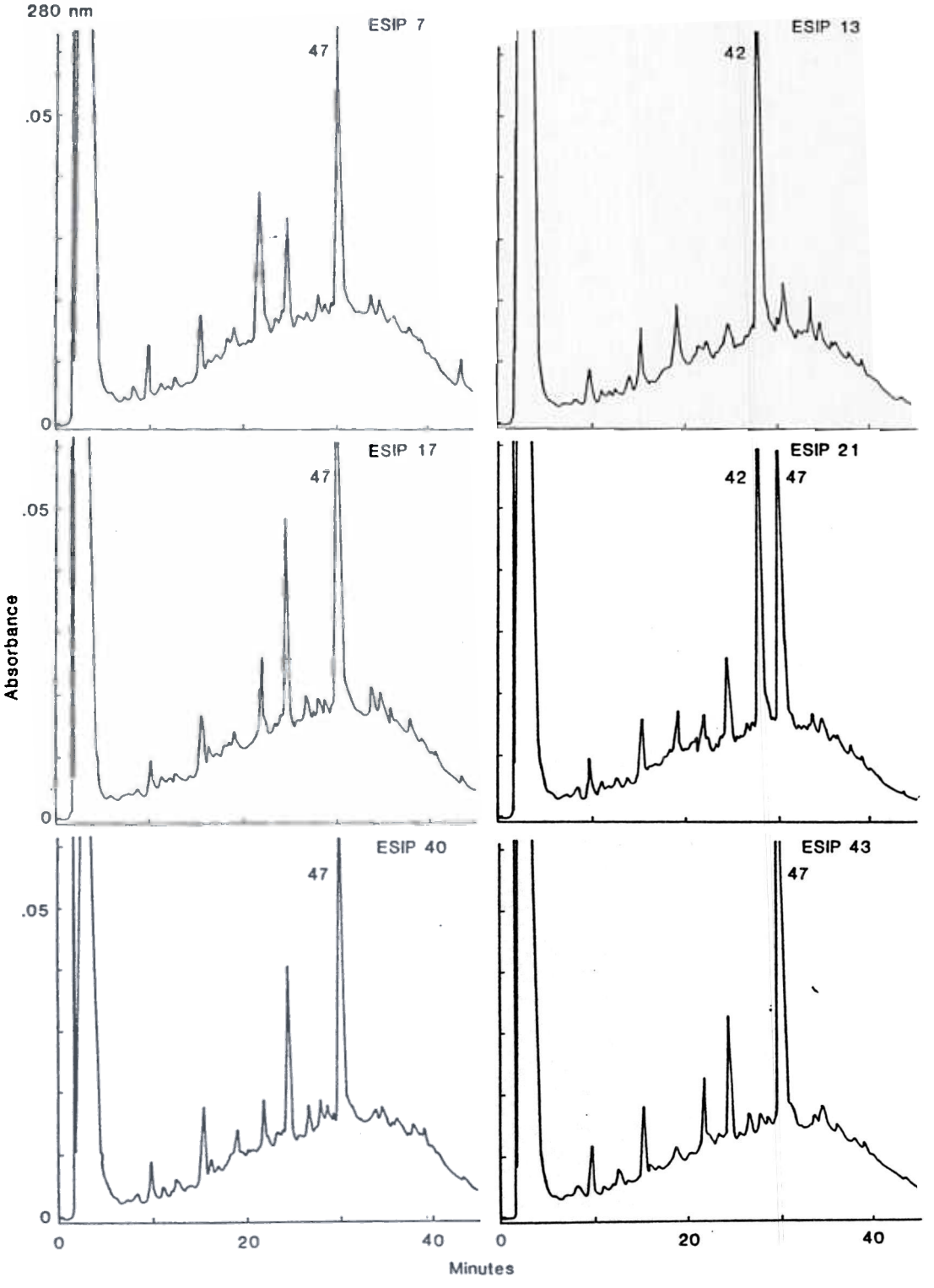

280 nm
ESIP 7
47
.05
0
ESIP 13
42
ESIP 17
47
.05
0
ESIP 21
42
47
Absorbance
ESIP 40
47
.05
0
ESIP 43
47
0
20
40
0
20
40
Minutes

Fig 6b

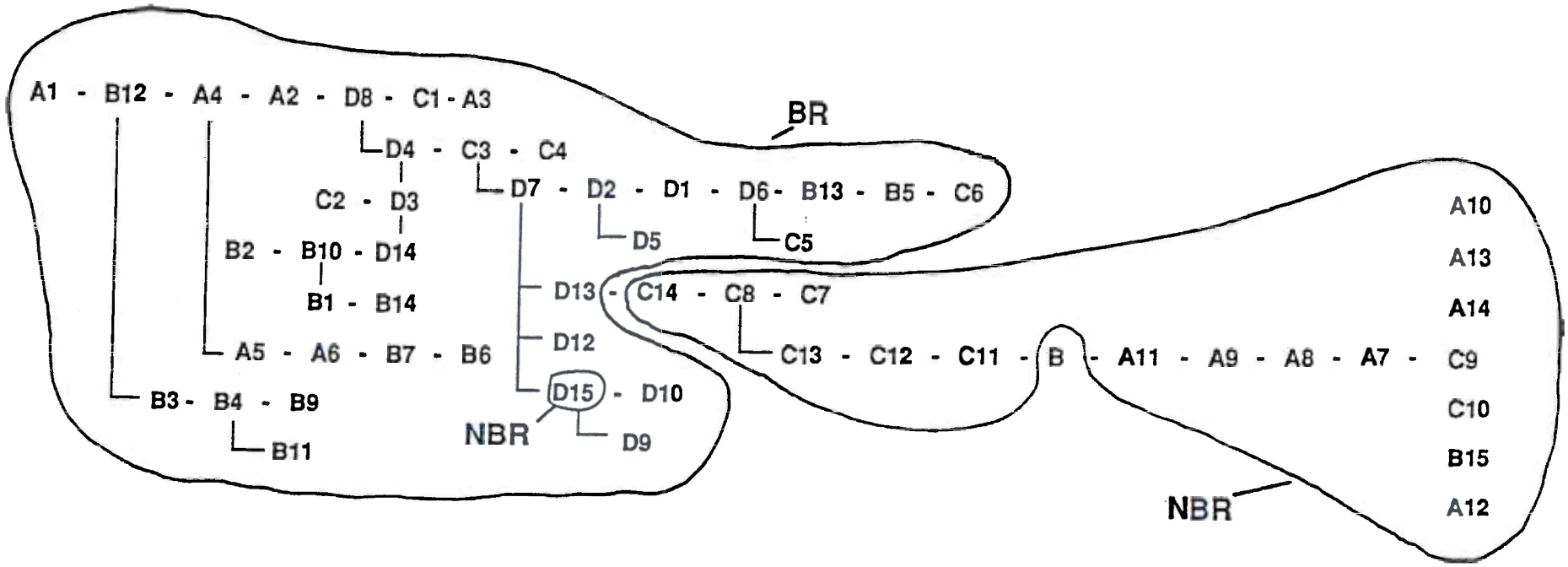
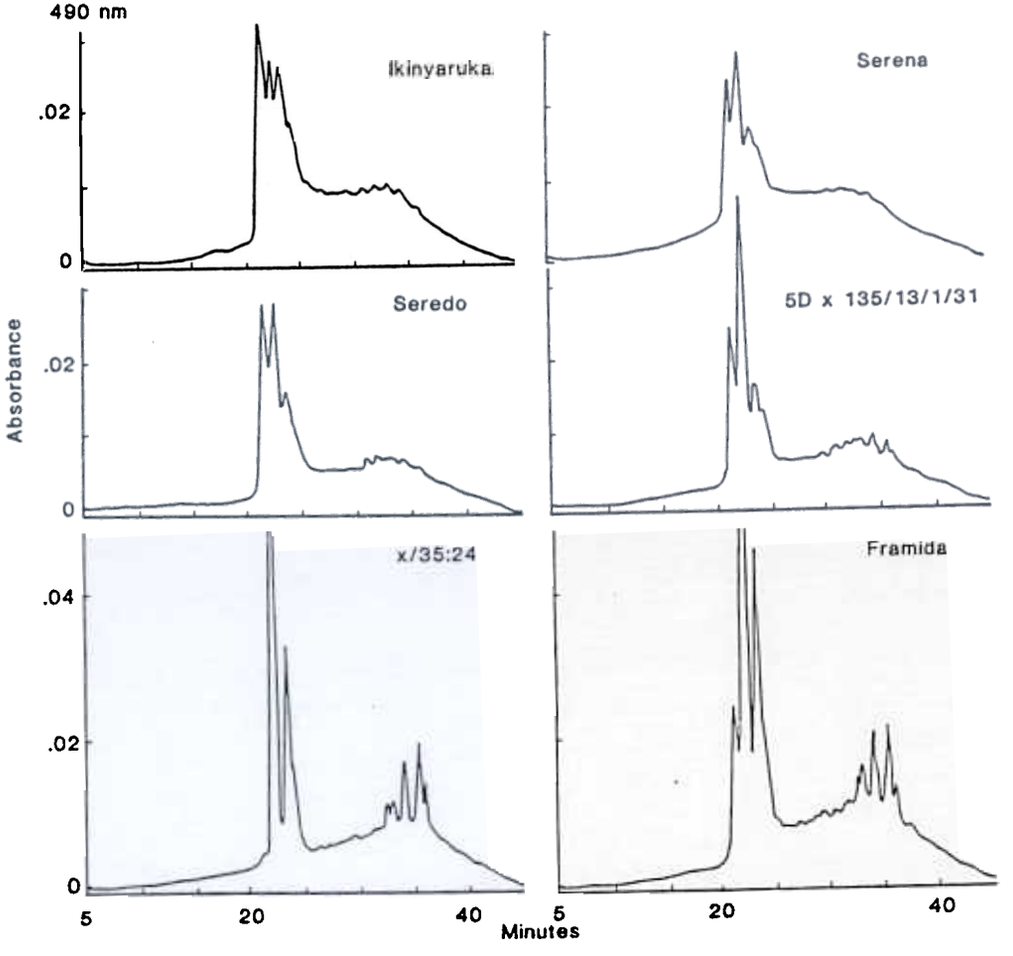

A1 - B12 - A4 - A2 - D8 - C1 - A3
D4 - C3 - C4
C2 - D3
D7 - D2 - D1 - D6 - B13 - B5 - C6
B2 - B10 - D14
D5
C5
BR
B1 - B14
D13 - C14 - C8 - C7
A5 - A6 - B7 - B6
D12
C13 - C12 - C11 - B - A11 - A9 - A8 - A7 -
A10
A13
A14
C9
C10
B15
A12
B3 - B4 - B9
D15 - D10
NBR
B11
D9
NBR

Fig 8a


490 nm
Ikinyaruka
Serena
Seredo
5D x 135/13/1/31
x/35:24
Framida
Absorbance
.02
0
.04
.02
0
5
20
40
5
20
40
Minutes

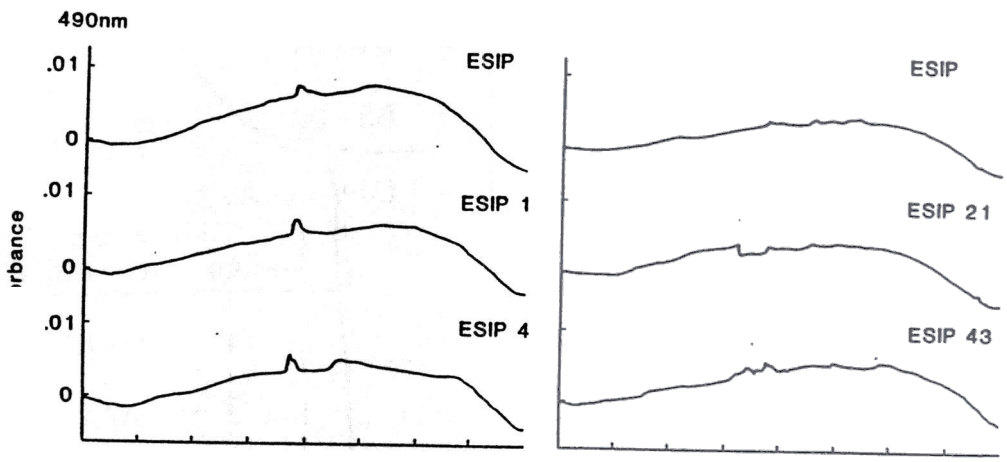
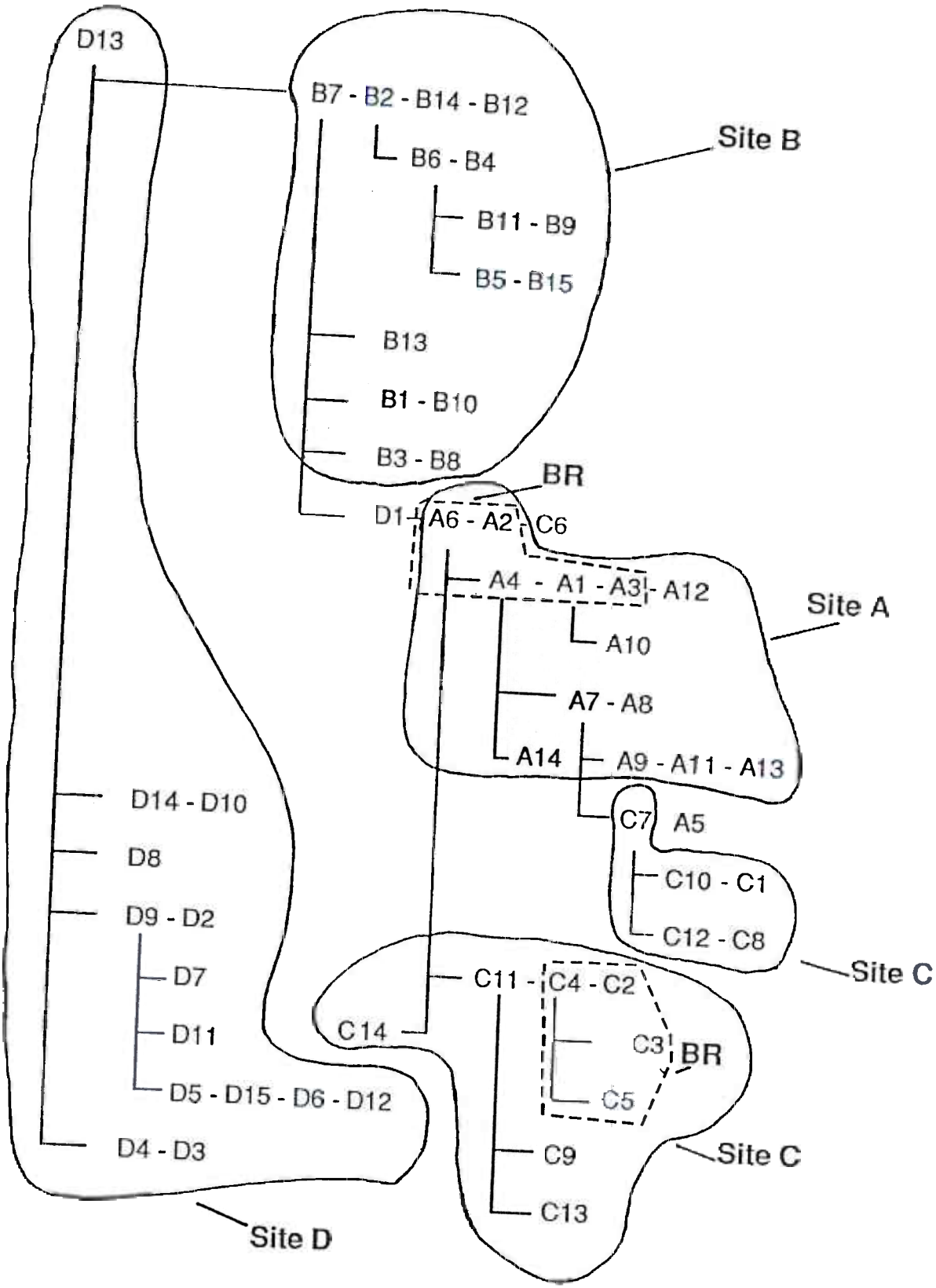


Fig 56


D13
B7 - B2 - B14 - B12
B6 - B4
B11 - B9
B5 - B15
Site B
B13
B1 - B10
B3 - B8
BR
D1
A6 - A2
C6
A4 - A1 - A3
A12
A10
Site A
A7 - A8
A14
A9 - A11 - A13
C7
A5
C10 - C1
C12 - C8
Site C
D14 - D10
D8
D9 - D2
D7
D11
D5 - D15 - D6 - D12
D4 - D3
C11 - C4 - C2
C14
C3
BR
C5
C9
C13
Site C
Site D

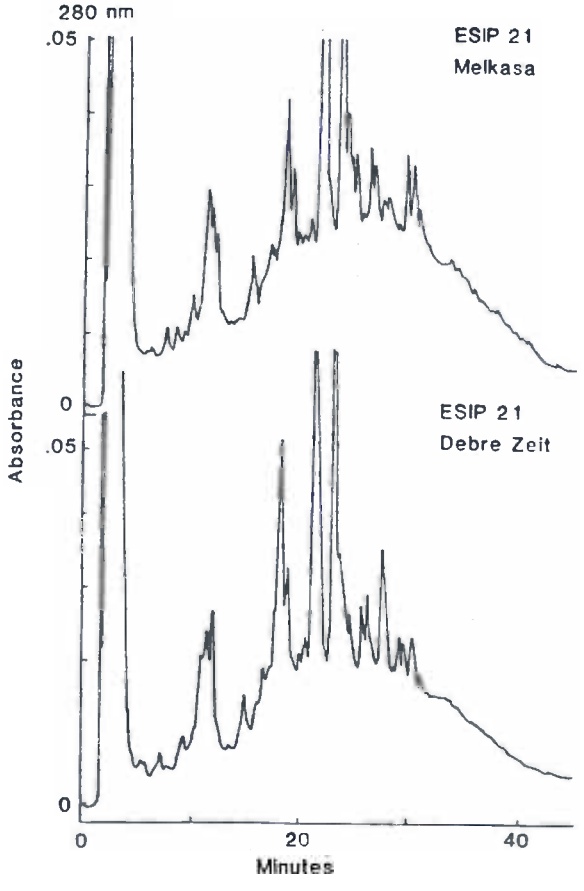

280 nm
.05
ESIP 21
Melkasa
0
.05
ESIP 21
Debre Zeit
0
Absorbance
0
20
40
Minutes

Fig 10a

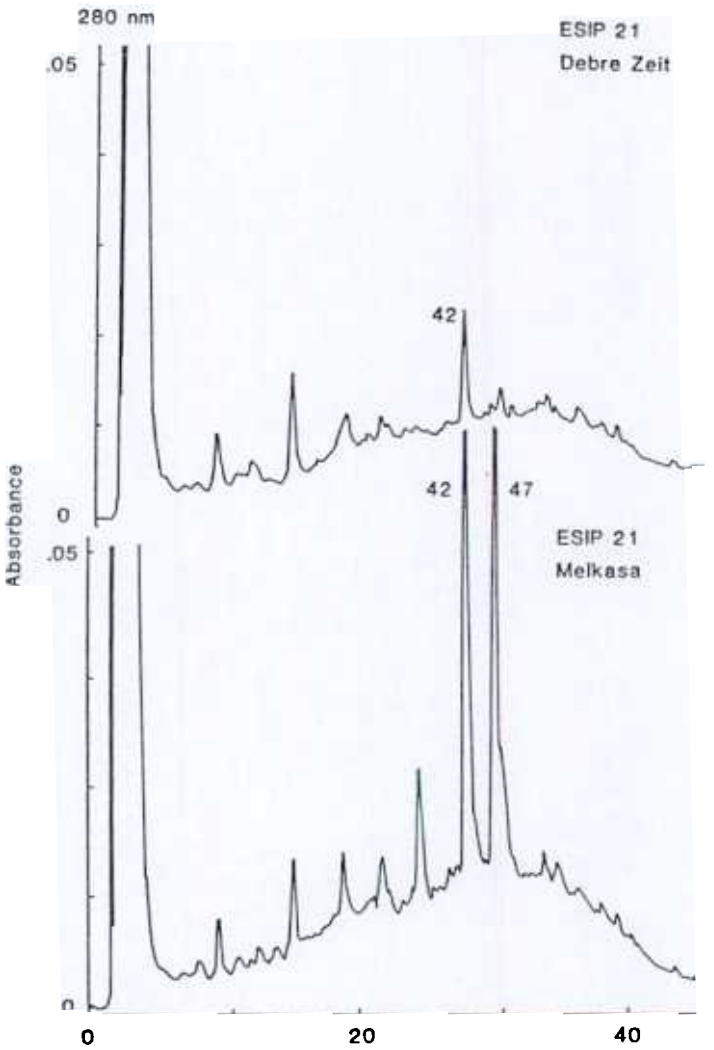

280 nm
ESIP 21
Debre Zeit
.05
0
42
42
47
ESIP 21
Melkasa
.05
0
Absorbance
0
20
40

Fig 10b

Phenolic compounds and their relationship to *in vitro* digestibility of sorghum leaves from bird- and non bird-resistant varieties

I. Mueller-Harvey[1] and J D Reed[+]

[1] AFRC Institute of Grassland and Environmental Research, Hurley, Maidenhead, Berks SL6 5LR, England

[+] Department of Meat and Animal Science, University of Wisconsin-Madison, 1675 Observatory Drive, Madison, Wisconsin 53706-1284, USA

(Received ; accepted)

ABSTRACT

Sorghum leaf blades and sheaths were examined after grain harvest for soluble phenolics. Apigenin and luteolin together with their 7-O-glucosides, p-coumaric acid, butin and apigeninidin were identified. This is the first reported finding of butin in sorghum tissues. Derivatives of luteolinidin, chalcone and flavanone and/or dihydroflavonol together with several other derivatives of cinnamic acid, apigenin, luteolin and apigeninidin were also detected. The composition of phenolics was clearly different between leaf blades (LB) and sheaths (LS). In addition, LS of bird- (BR) and non bird-resistant (NBR) varieties were also different. Biosynthesis of flavonoids appears to diverge at the flavanone/dihydroflavonol stage between BR- and NBR-varieties.

Several negative correlations were found between HPLC peaks and in vitro digestibilities. These were highly significant with butin and

significant with several luteolin derivatives but only with one apigenin derivative. Butin in turn was highly negatively correlated colorimetric measurements of 3-desoxyanthocyanidins. This may suggest that butin - rather than the 3-desoxyanthocyanidins as previously reported - is implicated in reducing dry matter digestibility.

words: Sorghum, leaves, cultivars, bird resistance, HPLC, post-column derivatisation, phenolics, anthocyanidins, flavones, flavanones, dihydroflavonols, cholcones, cinnamic acids, in vitro digestibility.

INTRODUCTION

Sorghum stover is an important feed resource for ruminants in many developing countries and research efforts are being directed towards identifying cultivars with improved digestibility characteristics (Reed et al 1988). It has been suggested that phenolic compounds are one of the factors which limit the digestion of carbohydrates in fibrous crop residues (Hartley and Jones 1978). Therefore a better understanding of the phenolic compounds present in sorghum stover and the factors controlling them will aid the development of more nutritious stover.

The synthesis of phenolics in plants can be affected by environmental factors, such as stress during growing conditions (Mueller-Harvey 1989 We recently demonstrated that such factors also influence the composition of phenolics in sorghum with some varieties exhibiting

stronger genotype x environment interactions than others (Mueller-Harvey and Dhanoa 1991). No detailed study has yet been made of the types of phenolics which are most influenced by environmental factors with two exceptions. Stafford (1969) studied the effect of light on young sorghum leaves and Nicholson et al (1988) studied the response to fungal infection on anthocyanidin synthesis. LINK?? This kind of information is required to 'address the task of evolving a new kind of production technology for the stress environment' (Jain 1988) if we are to make better use of crop residues.

Sorghum plants produce large amounts and a great diversity of phenolic compounds (Butler 1988). Some of which have biological activities, such as fungitoxicity (Doherty et al 1987; Jambunathan et al 1990; Snyder and Nicholson 1990), feeding deterrency (Dreyer et al 1981; Woodhead 1981) and digestion or fermentation inhibiting properties (Reed et al 1987; Waniska et al 1988).

Several cinnamic acid derivatives (Ring et al 1988; Eraso and Hartley 1990), monomeric and oligomeric flavonoids (Gupta and Haslam 1978; Gujer et al 1986; Butler 1989) occur in sorghum tissues. concentrations of these phenolics tend to change with tissue age. The greatest overall concentrations of free phenolic compounds, determined by a nonspecific colorimetric assay, occurred between 5 to 22 days after anthesis (DAA) in the caryopsis and glume (Doherty et al 1987) Ring et al (1988) similarly reported highest levels at 15 DAA, i.e. at the dough stage, in caryopsis, glume, peduncle and stalk; however, the trend was less clear in leaves. Only a few studies have examined the changes of individual compounds. Chromatographic analysis showed

that phenolic acid concentrations were higher in younger upper leaves than in more mature lower leaves (Ring et al 1988) Jambunathan et al (1990) and Watterson and Butler 1983) showed that flavan-4-ol concentrations were high at early maturity and drastically reduced at late maturity in grain and leaf. In contrast, anthocyanidin concentrations increased in senescing leaf tissues (Ring et al 1988).

Changes in phenolic concentrations during plant development are to be expected. Synthesis, degradation and mobilization of phenolics common at various stages of growth and some 'characteristic' phenolics may even disappear completely upon further growth (Barz and Hoesel 1979; Barz 1980). It was for these reasons that the results of phenolic composition of immature leaves reported previously could not be assumed to apply to leaves harvested at grain maturity and that this study was undertaken

MATERIALS AND METHODS

Materials:

Twenty four sorghum varieties were grown at Melkasa, Debre Zeit Dukam, Ethiopia, using a completely randomized block design and were harvested at full grain maturity (see Mueller-Harvey and Dhanoa 1991 for further details). Leaves were separated into leaf blade (LB) and leaf sheath (LS) fractions.

Phenolic standards:

All authentic flavonoid samples were purchased from Apin Chemicals, Abingdon, Oxon, UK and p-coumaric acid from Koch Light, Haverhill, UK

Methods:

Samples were extracted with aqueous acetone, phenolics separated by high performance liquid chromatography (HPLC) and peak heights integrated as described (Mueller-Harvey and Dhanoa 1991)

A280, A550, Insol. proanthocyanidins (=pigments), lignin:

In vitro digestibilities:

Correlations between phenolic peak heights and digestibilities:

Multiple regression analysis (GENSTAT 1987) was used to select a group of six HPLC peaks which described best maximum variation in the digestibility (NDFD, IV) and phenolic (A280, A550, IA, lignin) measurements. Heights and areas of individual HPLC peaks were used for the regression analysis in order to focus identification of compounds on a subset rather than all 70 compounds detected by HPLC. This approach assumes that peak heights or areas are linearly correlated with phenolic concentrations. Obviously, this assumption may not be true for all peaks but was used as a first approximation.

Identification or characterisation of phenolics:

Preliminary classification of phenolic compounds was carried out after HPLC post-column reaction with shift reagents (Mueller-Harvey and Blackwell, 1991). Having thus established the presence of cinnamic acid or flavonoid derivatives, unknown compounds were verified by co-chromatography with authentic phenolics. The spiked concentration of an authentic compound was adjusted so as to double the peak height of the unknown compound thus facilitating verification of retention

ime ddi pe id i i h ked th poi
ch iked pe k pw d pe d ape
i h W ka (M ipo W W d

RESULTS

Ph li compo ds l b

Fl

Le d phe pe k (# The
id i i y pect opy roma ography i
-g geni pe y (T)
y li api i # and
te ed l i y l pe k # nd
i i ti 0 th (#) ed th
pect. i 0 id Tab
h i i i pe k # Th l
pe i ime h i y i y
ams Co-c oma graphy ith l i
d i i i i i amen
iap i) d i (i i d
i i i time pe ks #2

NTO U N A th h i in i
i y ommo t p
ld t be d ed i gh LR (rbo

Two po k # h pe hi h mb ed
pec h Mah et al

dihydro:y ime ho l: vone (pec .i Tab
1) owe o-chroma og phy owed h ey di
compounds The pec um compound # ab) uggests impl
thyl ted vone (Mabry et al)

Phen .i eaths

Flavone

Fi nd how HPLC oma og ams LS ph i rom BR nd BR
i:ti T b nd he UV i absorp on maxima al
HPLC pe ks # he ame as LR nd
pige i: **T b** Peaks and ga .i type pectr bu
h i ed he LR one pe ks #
were l pres i LS

F vanon /dihydrofl vonol

.g h pec peak i ha .i
anones/dihydro vono Mabry et al Band maxima
b be t ca and ba occurr de ca
One hes pe identi ied bu in king **h**
d hyd: bi .i .iqu .t: ge .i ed to i .i y
he **fi** ompound (peaks and Tabl

C

ab) nd h yp con pec i h h
i p i maximum ( ) Mabry et al)
pect copy i omb th h: th #
h i OH ps i h (KO
phosph) i i A· i ps (bori i
Bohm) # h i OH-g: (bo i id
(KOH he i ed i i y

Ci ami id

p-C i i (pe k i ed pe py (hl
h: oma hy he ompound h pec
i ami i ed bu h ed
rth

An hocy id

i PLC hroma og ams y i LS pe d
h h y i i pe k i k (
i) mi i i di
h pe h pe orp i (A h
i i ab rbed i LC
empl ed h i l th h po
i th nd i -HC (bo)
i h i i h hoch: omi y
he bo i ed
i l i i h y i d yc
d ey) y y hyd

anthocyanidins tends to cause small hypsochromic shifts (Markham and Mabry 1975) It is possible that the rules derived from 3-OH anthocyanidins do not apply strictly to 3-desoxyanthocyanidins

Compound #30b (R_t = 20.9 min; Fig 3a and b) was identified as apigeninidin (Table 3). Peak #32b (R_t = 21.8 min) is an apigeninidin derivative judging from its spectrum (Table 3). Absorption of band I is shifted by -3 nm (470 nm) compared to authentic apigeninidin (473 nm) indicating possibly B-ring methylation (Strack and Wray 1989). As it elutes after apigininidin it could be either a methylated (Harborne and Boardley 1984 or an acylated apigeninidin derivative (Strack and Wray, 1989). This compound exhibited far greater resistance to prolonged hydrolysis in ButOH-HCl (95 °C for 1 hr, unpublished results than the luteolinidin derivatives (#28 and 30a) and could therefore have a glucuronide group attached (Markham 1982). Stafford 1965 previously reported a sorghum anthocyanidin linked to an unknown aliphatic organic acid.

Inspection of the HPLC chromatograms at 490 nm revealed another set of compounds - apart from peaks #28 to 32b - absorbing in the visible region having retention times between 30 and 35 min (Fig 4 Their band I absorption maxima at 482 nm suggested luteolinidin derivatives. One of these compounds (#53) also appeared to have a cinnamic acid derivative attached. In one of the varieties, 5DX160, the E_{max} acid/E_{max} pigment ratio was 55% thus indicating a molar acid to pigment ratio of 1:1 (Harborne 1958).

Multiple regression analysis between HPLC peaks and digestibility parameters:

Leaf blades:

Table 4 lists the HPLC peaks which were selected by multiple regression analysis to describe the variation in digestibility and several colorimetric phenolic measurements of LB. It can be seen that several luteolin derivatives, including luteolin itself (#35, 42, 50, 58), had negative correlations with digestibilities (t-values: -2.80, -5.21, -3.03 and -3.77 resp.) However, only one of the apigenin derivatives (#27), thought to be a dimer, showed a slight negative correlation (t=-2.73) with IV-digestibility. One other flavone derivative, peak #50, was also correlated negatively with digestibilities.

It is noteworthy that luteolin (#42) [and its derivatives (#35, 50, 58)] had the strongest negative correlation with digestibility and the strongest positive correlation with lignin (t-value = 4.11) and A280 (#29: t = 5.59) or A550 (#42: t = 5.30). However, apigenin (#47) or its 7-O-glucoside (#32a) had only negative correlations with A550 (#32a: t = -2.92) and IA (#47: t = -2.36)

Leaf sheaths:

Table 5 lists those HPLC peaks which describe best the variation in degestibility and colorimetric phenolic measurements in LS. The negative correlations between butin (peak #26) and the digestibility parameters are highly significant (with NDFD t=-5.40; with IV t = 3.66, these are significant at P = 0.0).

In addition, negative correlations with digestibility were observed for a flavanone/dihydroflavonol (#38), a luteolin derivatives (#58) p-coumaric acid (#17) and finally a flavone (#50). Only one of apigenin derivatives showed a slight negative correlation digestibility in leaf sheaths. It is worth noting that two compounds (#17 and 46) having positive correlations with lignin also exhibited negative correlations with digestibility.

DISCUSSION

Clearly, luteolin and its derivatives make a significant contribution to reduced digestibility, whereas a selection of varieties for apigenin or its derivatives would increase digestibility.

Phenolic composition of sorghum leaf blades and sheath at grain maturity:

This study provides the first report of several chalcones flavanones (including butin occurring in sorghum LB and LS. Previous reports have recorded the occurrence of chalcone, naringinochalcone, and the flavanones, naringenin and eriodictyol in grain (Butler 1989; Gujer et al 1986). However, tests for naringenin and eriodictyol in leaf tissues were negative. Previous reports have in fact indicated that the phenolic composition differs between sorghum plant fractions (Ring et al 1988; Butler 1989; Mueller-Harvey and Dhanoa 1991) distribution of various flavonoid classes amongst different tissues can now be categorised in Fig 6. This figure is an adaptation of Heller and Forkmann's 1988) scheme which describes in general biosynthetic reaction steps leading to various flavonoid classes.

id l hich h i i i

-O-g mi h

b (i nd ni i -O-g ide

) i) i and)

H LC pe k i (be nd

d y h y i i nidi pi i idi

i i i d i # nd h i i

LS h i be he LC pe k

mbe omp nd ich h i ir onoi

id i i

ummar h h h y nd de

p omi LS BR i LS

i /d yd o-oc th

d h di anone/ i y. h

i i l k i LS R i i The he i

ich y i i th ai BR

i i W imi y pas h h

dihy nd kma hi g h

bi y h i h i / ihy l

be i i

D i ph i LS R d NB

W y (M l. y nd po ed C

pl LS y d

h mp k

h ed

(i) Lu linidin and apigenini i de i ives occu in l hea hs BR- bu not NBR i (Fi nd

(ii) peak particular ap nin and/ occasi y occu NBR LS (peaks #4 and res Fig) Whi hoc dins were i NBR LS mall pe p gen and l teo in det ed in BR- compared to NBR LS Fi Th ge pplied bu he sampl examined ii) Dihy l l / l common LS BR i bu ins gni ican not in NBR- arieti

The i de i (peak #) toge her th p geni d #) occu i he amp ysed The ig i i i d (occ in nd he econd l li i deri i (a in only o the ample i ho et al ob ed ha ap ge i i he mos commo qmen No l ide coul he ovided he eolinidi lycone ny he amp bec use i co-e ed ith # b Howe sma lini i may ha been i the hea hs vari i (l 1 and SUSA This is he composi i you h hoo wh te i i i hocy i (St ord

heno ompo i in l ion to in vitro ge ibi i i This udy ha hown ha amongs the avones hree l in de i i pi in i i nd one de i (# nega i corre ed i h in vitro d ges ibi anones/d ydro l (exhib ed eg l T 4 and l in parti l

bu h d y h i l i
di i i y Th y t i-OH pin in th i
(Fi) j owe di i i iti et
al) po ed imi bs Th pr i
(=C y li d i i l was
i h di i

i po h pr enc ed igme
d y hoc i i h i d i i ed h po
in vitro i i iti R et al) h y po ed
t i i ompo wi h q i y
pa Th eg i i i i
bu y l ed i h
h y i i eme h A)
d i l y i A) ( ) (l
) ti y poi t ks id
h ime h eq i ed i
t ni ho ph whi h h
dy h y be rmf dry di

mmary one y
i N i i L BR
i h / dr oq h
-d y hocy h yn con i h h
y i i W d
imi y i l
kma t i i

threshold exists at the flavanone/dihydroflavonol stage between sorghum tissues of NBR- and BR-varieties.

ACKNOWLEDGEMENTS

The authors are grateful to Mr M S Dhanoa for the correlation analyses; to Dr Y Kebede, Institute of Agricultural Research, Nazret, Ethiopia for his valuable assistance with the sorghum field experiments; to Mr P M S Blackwell for his patience and skill in performing the HPLC analysis; to Dr A B McAllan for critically reading the manuscript and to the International Livestock Centre for Africa, Addis Ababa, Ethiopia for providing facilities and logistic support We also thank LKB/Pharmacia (Milton Keynes, UK) for the loan of a P-500 pump for the HPLC post-column reactions.

This project (contract number EMC X0093) was funded by the Overseas Development Administration. Sorghum samples were imported under licence number PHF 976/37/119 issued by the Ministry for Agriculture, Fisheries and Food.

REFERENCES

Barz W 1980 Degradation of Flavonoids and Isoflavonoids. In: *Pigments in Plants*. ed Czygan F C. Gustav Fischer Verlag, Stuttgart, Germany. 2nd edition. pp. 210-223

Bohm B A 1989 Chalcones and Aurones. In: *Methods in Plant Biochemistry. Vol 1 Plant Phenolics*, ed Harborne J B. Academic Press Ltd, London. p 243.

Butler L G 1988 The role of polyphenols in the utilization of ICRISAT-mandated grain crops and applications of biotechnology for improved utilization. Biotechnology in tropical crop improvement: *Proc Int Biotechnology Workshop*, 12-15 Jan 1987, International Crops Research Institute for the Semi-Arid Tropics, Patancheru, A.P. 502 324, India. pp. 147-152.

Butler L G 1989 Sorghum Polyphenols. Chapter 5 in: *Toxicants of Plant Origin. IV. Phenolics*, ed Cheeke P R. CRC Press, Inc., Boca Raton, Florida, pp.95-121.

Doherty C A, Waniska R D, Rooney L W, Earp C F, Poe J H 1987 Free phenolic compounds and tannins in sorghum caryopsis and glumes during development. *Cereal Chem* **64** 42-46.

Dreyer D L, Reese J C, Jones K C 1981 Aphid feeding deterrents in sorghum. Bioassay, isolation, and characterization. *J Chem Ecol* **7** 273-284.

Eraso F and Hartley R D 1990 Monomeric and dimeric phenolic constituents of plant cell walls - possible factors influencing wall biodegradability. *J Sci Food Agric* **51** 163-170.

GENSTAT 5 Reference Manual 1987. Clarendon Press, Oxford.

Gujer R, Magnolato D, Self R 1986 Glucosylated flavonoids and other phenolic compounds from sorghum. *Phytochem* **25** 1431-1436.

Gupta R K and Haslam E 1978 Plant proanthocyanidins. Part 5. Sorghum polyphenols. *J Chem Soc Perkin Trans I* 892-896.

Harborne J B 1967 *Comparative Biochemistry of the Flavonoids*. Academic Press, London. p. 51.

Harborne J B and Boardley M 1984 Use of high-performance liquid chromatography in the separation of flavonol glycosides and flavonol sulphates. *J Chromatogr* **299** 377-385.

Harborne J B 1958 Spectral methods of characterizing anthocyanins *Biochem J* **70** 22-28.

Harborne J B and Hall E 1964 Plant polyphenols-XII. The occurrence of tricin and of glycoflavones in grasses. *Phytochem* **3** 421-428.

Hartley R D and Jones E C 1978 Phenolic components and degradability of the cell walls of the brown midrib mutant, bm_2, of *Zea mays*. *J Sci Food Agric* **29** 777-789.

Heller and Forkmann 1988. Biosynthesis. Chapter 11 in *The Flavonoids* (J B Harborne, ed.). Chapman and Hall Ltd, London. pp 399-425.

Jain H K 1988 Role of research in transforming traditional agriculture: an emerging perspective. *ISNAR Reprint Series* No 4. International Service for National Agricultural Research, The Hague, Netherlands.

Jambunathan R, Kherdekar M S, Bandyopadhyay R 1990 Flavan-4-ols concentration in mould-susceptible and mole-resistant sorghum at different stages of grain development. *J Agric. Food Chem* **38** 545-548.

Julian E A, Johnson G, Johnson D K, Donnelly B J 1971 The glycoflavonoid pigments of wheat, *Triticum aestivum*, leaves. *Phytochem* **10** 3185-3193.

Mabry T J, Markham K R, Thomas M B 1970 *The Systematic Identification of Flavonoids*. Springer Verlag, New York.

Markham K R and Mabry T J Ultraviolet-visible and proton magnetic resonance spectroscopy of flavonoids. Chapter 2 in: *The Flavonoids*. eds Harborne J B, Mabry T J, Mabry H. Academic Press, New York. p 55.

Markham K R 1982 *Techniques of Flavonoid Identification*. Academic Press. London. p 53.

Mueller-Harvey I, McAllan A B, Theodorou M K, Beever D E 1988 Phenolics in fibrous crop residues and plants and their effects on the digestion and utilisation of carbohydrates and proteins in ruminants. In: *Plant Breeding and the Nutritive Value of Crop Residues*, eds Reed J D, Capper B S, Neate P J H. Proceedings of a workshop held at the International Livestock Centre for Africa, Addis Ababa, Ethiopia, 7-10 December 1987. ILCA, Addis Ababa. pp. 97-132.

Mueller-Harvey I 1989 Identification and importance of polyphenolic compounds in crop residues. In: *Physico-chemical characterisation of plant residues for industrial and feed use*, eds Chesson A and Orskov E R, Elsevier Applied Science, London. pp. 88-109.

Mueller-Harvey I and McAllan A B 1992 Tannins - Their Biochemistry and Nutritional Properties. In: *Advances in Plant Cell Biochemistry and Biotechnology* (I. M. Morrison, ed.). JAI Press Ltd., London (in press).

Mueller-Harvey I and Blackwell P M S 1991 An improved high performance liquid chromatographic post-column derivatization procedure for the uv-vis spectroscopic characterization of phenolic compounds. *Phytochemical Analysis* **2** 38-42.

Mueller-Harvey I and Dhanoa M S 1991 Varietal differences amongst sorghum crop residues in relation to their phenolic HPLC-fingerprints and responses to different environments. *J Sci Food Agric* (in press)

Nicholson R L, Kollipara S S, Vincent J R, Lyons P C, Cadena-Gomez G 1987 Phytoalexin synthesis by the sorghum mesocotyl in response to infection by pathogenic and nonpathogenic fungi. *Proc Natl Acad Sci USA* **84** 5520-5524.

Nicholson R L, Jamil F F, Snyder B A, Lue W L, Hipskind J 1988 Phytoalexin synthesis in the juvenile sorghum leaf. *Physiol Mol Plant Pathol* **33** 271-278.

Reed J D, Tedla A, Kebede Y 1987 Phenolics, fibre and fibre digestibility in the crop residue from bird resistant and non-bird resistant sorghum varieties. *J Sci Food Agric* **39** 113-121.

Ring A S, Waniska R D, Rooney L W 1988 Phenolic compounds in different sorghum tissues during maturation. *Biomass* **17** 39-50.

Snyder B A and Nicholson R L 1990 Synthesis of phytoalexins in sorghum as a site-specific response to fungal ingress. *Science* **248** 1637-1638.

Stafford H A 1965 Flavonoids and related phenolic compounds produced in the first internode of Sorghum vulgare Pers. in darkness and in light. *Plant Physiol* **40** 130-138.

Stafford H A 1969 Changes in phenolic compounds and related enzymes in young plants of sorghum. *Phytochem* **8** 743-752.

Strack D and Wray V 1989 Anthocyanins. Chapter 9 in: *Methods in Plant Biochemistry. Vol 1 Plant Phenolics*, ed Harborne J B. Academic Press Ltd, London. pp 338-340.

Waniska R D, Ring A S, Doherty C A, Poe J H, Rooney L W 1988 Inhibitors in sorghum biomass during growth and processing into fuel. *Biomass* **15** 155-164.

Watterson J J and Butler L G 1983 Occurrence of an unusual leucoanthocyanidin and absence of proanthocyanidins in sorghum leaves. *J Agric Food Chem* **31** 41-45.

Williams C A 1989 Biflavonoids. In: *Methods in Plant Biochemistry Vol 1 Plant Phenolics*, ed Harborne J B. Academic Press Ltd, London. pp. 357-388.

Woodhead S 1981 Environmental and biotic factors affecting the phenolic content of different cultivars of Sorghum bicolor. *J Chem Ecol* **7** 1035-1047.

TABLE 1

UV-Vis absorption maxima (nm) of selected phenolics from leaf blades before (MeOH/H2SO4) and after addition of shift reagents (KOH, Na2HPO4, AlCl3/H2SO4, H3BO3/NaOAc) (ALB11)

HPLC peaks	MeOH/ H_2SO_4	KOH	Na_2HPO_4	$AlCl_3$/ H_2SO_4	H_3BO_3/ NaOAc
Luteolin derivatives:					
#29	255	267	261	268	260
	266sh		-	294sh	
	287sh	300sh	295	356sh	292sh
	349	390	399	390	371
#34	252				
	267				
	348				
#35	245				
	268				
	292sh				
	337				
42	254	268	272	267	262
	264sh	-	-	-	-
	290sh	318	323	-	300sh
	350	402	390	396	374
authentic luteolin	242sh	238sh	269	266sh	259
	253	-	-	-	-
	267	270	-	275	-
	291sh	329sh	326sh	294sh	301sh
	349	401	384	355	370
				385	430sh
authentic luteolin 4'-O-glucoside	250				
	269				
	290sh				
	338				
Apigenin derivatives:					
#23	272	283	282	272	272
	-	-	312sh	-	-
	-	333	335	-	-
	334	402	396	337	335
#27	272		282	273	275
	298sh		-	-	303sh
	335		391	336	346

	-	240sh	255sh	-	-
	266	274	266	270	267
	-	303	291sh	297	-
	-	347sh	-	338	-
	335	378	388	386sh	337
	267	275	274	272	267
	294sh	323sh	310	297	-
	-	-	-	338	-
	338	392	390	381sh	341
authentic apigenin	268	275	275	272	269
	293sh	326	302	297	297sh
	-	-	-	338	-
	338	395	383	375sh	344
Other flavones:					
	270	27	277	274	
	-	29	298	299	
	328	36	367	332	
#50	271				
	-				
	333				
5,7-diOH-3',4',5'-triOMe flavone*	270	278	277	280	272
	310sh	300sh	299sh	298sh	313s
	331	367	359	340	330
				382sh	
Flavanone or dihydroflavonol:					
#46	298sh	310sh	318	298sh	298sh
	313	369	370	314	317

Explanations of HPLC peak numbers:
23 an apigenin derivative; 27 an apigenin dimer; 29 luteolin 7-O-glucoside; 32a apigenin 7-O-glucoside; 34 a luteolin derivative; 35 possibly luteolin 4'-O-glucosides; 39 a flavone derivative; 42 luteolin; 46 a flavanone or dihydroflavonol; 47 apigenin; 50 a flavone derivative.

* Spectral data from Mabry et al (1970)

TABLE 2

UV-Vis absorption maxima (nm) of selected phenolics from leaf sheaths of non bird resistant sorghum varieties before (MeOH/H2SO4) and after addition of shift reagents (KOH, Na2HPO4, AlCl3/H2SO4, H3BO3/NaOAc) (ASH9)

peaks	MeOH/ H_2SO_4	KOH	Na_2HPO_4	$AlCl_3$/ H_2SO_4	H_3BO_3/ NaOAc
Cinnamic acid:					
#17		254	286		
	297sh	309sh	304sh	295sh	285
	309	342	349sh	309	303sh
authentic p-coumaric acid			287		
	295sh	306sh	304sh	296sh	285
	311	335	347sh	308	298sh
Luteolin derivatives:					
#42 (see Table 1					
#48	252				253sh
	268	269	275		271
	291sh	306	310sh		
	348	399	390		354
	253				253
	267sh				267sh
	348				347
Apigenin derivative:					
#47 (see Table 1)					

Explanations of HPLC peak numbers:
17 p-coumaric acid; 42 luteolin; 47 apigenin; 48 and 58 luteolin derivatives.

TABLE 3

UV-Vis absorption maxima (nm) of selected phenolics from leaf sheaths of bird resistant sorghum varieties before (MeOH/H2SO4) and after addition of shift reagents (KOH, NaHPO4, AlCL3/H2SO4, H3BO3/NaOAc) (ASH6=IS8686, BSH6=Ikinyaruka). These peaks are present in addition to those listed in Table 2.

peaks	MeOH/ H_2SO_4	KOH	Na_2HPO_4	$AlCl_3$/ H_2SO_4	H_3BO_3/ NaOAc
Flavanones or dihydroflavonols:					
#22		254			
	277	285sh	283	275	
	310-385sh	330	332sh	310-390sh	
		415sh	ca 385		
		247sh	248sh		237
	277		281sh	295	290
	307	345	344	335	328
			249sh		
	277				
	306sh		347		
		250			
	278	293	284	285	287
	308sh	359 dec	336	367sh?	333
			425?		
#43	278			280	
	312			317sh	
				(or 335	
#52		248sh			
	283	286sh	285	278	284
	(323sh)	327	330	350	
				(343?	
authentic butin	279				
	311				
Flavone:					
#50	269	275	275		275
		300sh	303sh		
	337	371	370		340

3-Desoxyantho-cyanidins:					
#28	240sh	254sh	255sh	249	246
	279	297	291	281	285
	321sh			308	
	368sh	351sh	370	388sh	365sh
			467		450sh
		552	541	528	520
#30a	242sh	251		252	248sh
	279	295	303	278	284
	321sh			314	328sh
	362sh	364	360	409sh	
			474sh		446sh
		574	566	528	524
authentic luteolinidin	240sh				
	279				
	317sh				
	486	568*			
#30b		253	250sh	242	
	276	294	295sh	274	286
	321sh	360	356	321	327
	414sh	471sh	464sh	413sh	422
	474	533	536	473	503
#32b	242				
	278			276	
	323			323	
	400sh			412sh	
	470			469	
authentic apigeninidin	242				
	275				
	320				
	415sh				
	473	535*			
Chalcones:					
#31	249				
	376				
#32c	250	272sh	260sh	256	252
		316	350sh		
	377	447	423	384	390
#36		236			
	250sh			250sh	251sh
	306sh	346	349sh	303sh	299sh
	376	449	412	372	372

Explanations of HPLC peak numbers: 26 butin; 22, 33, 38, 43 and 52 flavanone or dihydroflavonol derivatives; 50 a flavone derivative; 28 and 30a luteolinidin derivatives; 30b apigeninidin; 32b an apigeninidin derivative; 31, 32c, 36 chalcone derivatives.
*) Spectral data from Stafford (1965).

TABLE 4a

Significant correlations between HPLC peak heights (in brackets: peak areas) of leaf blade phenolics with neutral detergent fibre- (NDFD) and <u>in vitro</u> (IV)-digestibilities, absorption measurements at 280 nm (A_{280}) and 550 nm (A_{550}) and lignin.

	HPLC peaks*				
	#29	#32	#42	#50	#58
NDFD		(3.9)	-2.8 (-5.1)	-3.0	-3.8
		(2.9)	-5.2	(-2.1)	(-2.7
	5.6				
		-2.9	5.3		
lignin			4.1		

*) See Table 4b for description of HPLC peak numbers.

TABLE 4

List of HPLC peaks (heights) from leaf blades which were selected in multiple regression analysis to describe maximum variation in digestibility and colorimetric parameters.

Parameters	HPLC peak numbers						R2
NDFD	-58	-50*	13	54	-35*	19	56.8
IV	38	-42*	24	-27*	7	12	63.2
A280	3	41	29*	-66	38	9	77.4
A550	38	31	42*	28	-32a*	64	48.7
Lignin	42*	-52	-13	44	10	-70	62.8
IA	64	4	-19	8	18	-47*	84.8

*) denotes that compound has been characterised, see footnote of Table 1 for further details.
**) R2 = variance accounted for, this is equivalent to corrected R2.

TABLE 4b

Correlation coefficients of pairwise correlations between HPLC peak heights of leaf blade phenolics and neutral detergent fibre (NDFD)- and *in vitro* (IV)-digestibilities and aqueous ethanol insoluble anthocyanidins (IA).

	HPLC peaks*			
	#42	#48	#50	#58
NDFD	-.47	-.32	-.34	-.39
IV	-.50	-.36	-.37	-.38
IA	-.38	-.30		

*) Explanations of HPLC peak numbers:
29 - luteolin 7-O-glucoside; 32 - apigenin 7-O-glucoside; 35 luteolin derivative; 42 - luteolin; 48 - a luteolin derivative; 50 - a flavone derivative; 58 - a luteolin derivative.

TABLE 5

List of HPLC peaks (heights) from leaf sheaths which were selected in multiple regression analysis to describe maximum variation in digestibility and colorimetric parameters.

Parameters	HPLC peak numbers						R2
NFDF	-26*	-58*	-9	-10	45	-46	56.8
IV	-26*	-17*	-58*	-38*	-50*	-10	53.1
A280	22*	26*	-56	35	55	42*	93.2
A550	26*	22*	-35	32b,c*	69	50*	93.1
Lignin	28*	17*	-64	34	-27	46	65.0
IA	26*	22*	-39	64	53	-41	93.8

*) denotes that compound has been characterised, see footnote of Tables 2 and 3 for further details.
**) R2 = variance accounted for, this is equivalent to corrected R2.

TABLE 5a

Significant correlations (T-values) between HPLC peak heights (in brackets: peak areas) of leaf sheath phenolics and neutral detergent fibre (NDFD)- and *in vitro* (IV)-digestibilities, absorption measurements at 280 nm (A_{280}) and 550 nm (A_{550}), aqueous ethanol insoluble anthocyanidins (IA) and lignin.

	HPLC peaks*						
	#17	#22	#26	#38	#42	#50	#58
NDFD	(-4.9)		-5.4				-3.8
IV	(-6.8)		-3.7	-2.7		-2.4	-2.5
A_{280}		13.1	13.0				
A_{550}		8.0	14.7			2.3	
IA		7.3	17.3				
lignin	4.2					3.7	

*) see Table 5b for description of HPLC peak numbers.

TABLE 5b

Correlation coefficients of pairwise correlations between HPLC peak heights of leaf sheath phenolics and neutral detergent fibre (NDFD)- or *in vitro* (IV)-digestibilities, absorption measurments at 280 nm (A_{280}) and 550 nm (A_{550}), aqueous ethanol insoluble anthocyanidins (IA) and lignin.

	HPLC peaks*								
	#17	#22	#26	#28	#29	#30	#31	#32	#33
NDFD	-.45		-.57	-.32	.41				
IV	-.51		-.54	-.31	.42				
A_{280}		.77	.63	.37		.65	.74	.70	.38
A_{550}	.32	.70	.81	.55	-.50	.60	.69	.70	.54
IA	.31	.50	.91	.38	-.38	.35	.49	.48	.62
lignin	.52			.54	-.35				

Table 5b cont.:

	#35	#36	#37	#38	#47	#48	#52
NDFD	.33		.40	-.44	.35	-.38	-.37
IV	.35		.40	.44	.37	-.40	-.38
		.69		.37			.54
A_{550}	-.30	.62	-.43	.37	-.39	.38	.53
IA		.42	-.30	.50			.65
lignin	-.31		-.45		-.36	.43	

Explanations to HPLC peak numbers:
17 - p-coumaric aicd; 22 - a flavanone or dihydroflavonol; 26 - butin; 28 a luteolinidin derivative; 29 - luteolin 7-O-glucoside; 30 - apigeninidin; 31 - unknown; 32 - apigeninidin derivative; 33 - a flavanone or dihydroflavonol; 35 - unknown; 36 - a chalcone; 37 - unknown; 38 - a flavanone or dihydroflavonol; 47 - apigenin; 48 - a luteolin derivative; 50 - a flavone; 52 - a flavanone or dihydroflavonol; 58 - a luteolin drivative.

Legend to Figures:

Figure 1: HPLC separation of leaf blade phenolics from sorghum variety (X/35:24) recorded at 280 nm.

Figure 2: HPLC separation of leaf sheath phenolics from a non bird resistant sorghum variety (ESIP 13) recorded at 280 nm.

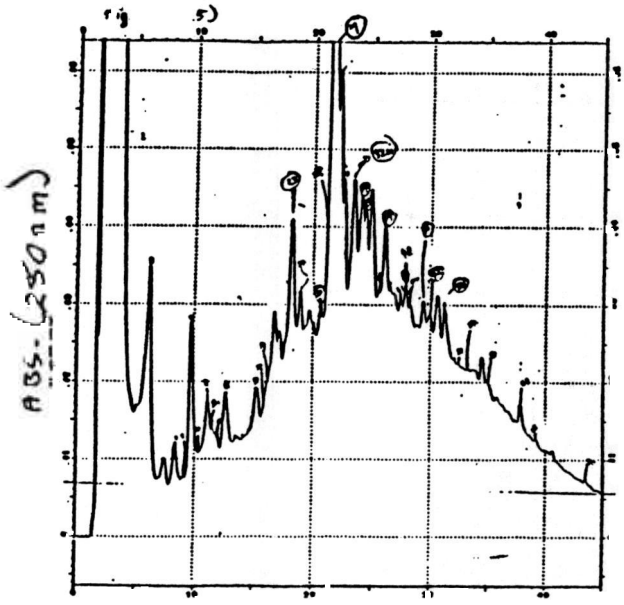
Figure 3: HPLC separation of leaf sheath phenolics, recorded at 280 nm, from bird resistant sorghum varieties: a) Seredo grown at Debre Zeit, b) Seredo grown at Melkasa, c) Ikinyaruka grown at Melkasa.

Figure 4: UV-spectra of several leaf sheath phenolics from bird resistant varieties having spectra characteristic of flavanones and/or dihydroflavonols (see Table 3 and Fig 3 for information on peak numbers #13, #26, #33, #38).

Figure 5: HPLC separation of leaf sheath phenolics from a) a bird resistant variety (5Dx160) and b) a non bird resistant variety (ESIP 7) recorded at 490 nm.

Figure 6: UV-Vis spectrum of an acylated luteolinidin derivative, peak #55 from sheath of 5Dx160.

Figure 7: Routes of flavonoid biosynthesis in leaf blade, sheath and grain from bird- and non bird resistant sorghum varieties (adapted from Heller and Forkmann 1988).



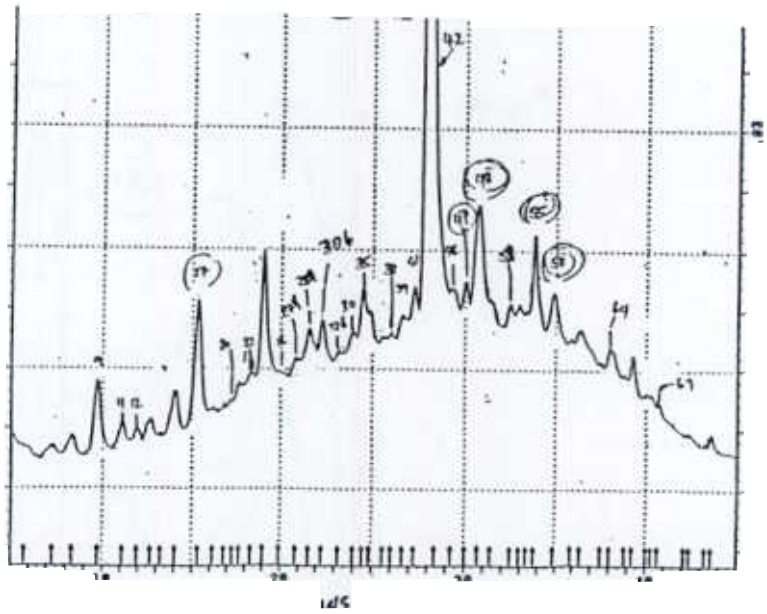


Fig. 3a (CSH3)

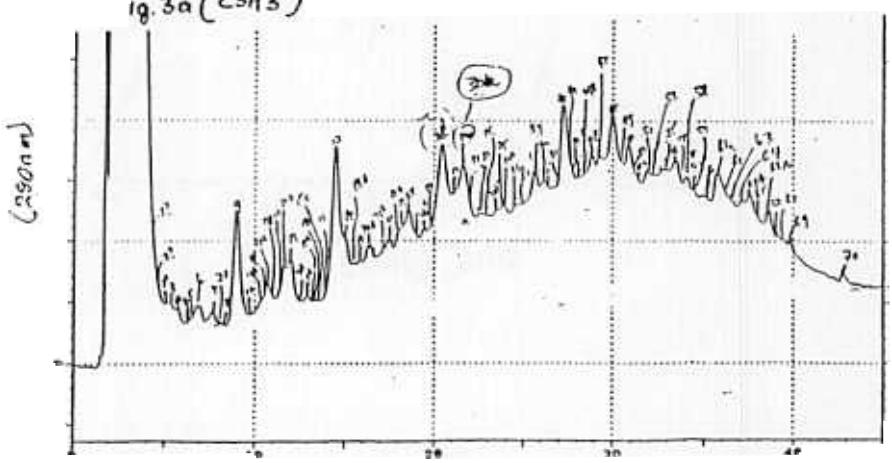


Fig. 3b (ASH3)

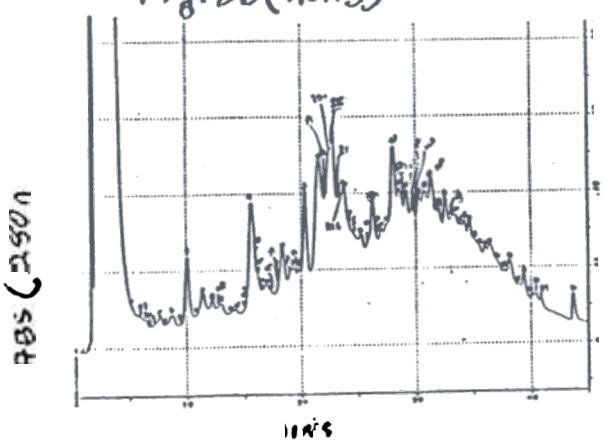


Fig. 3c (BSH6)

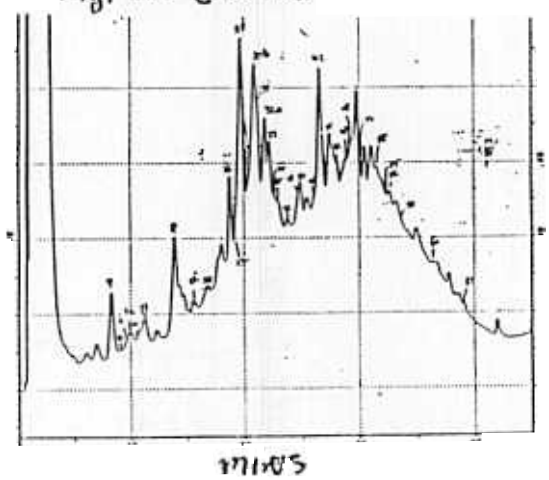
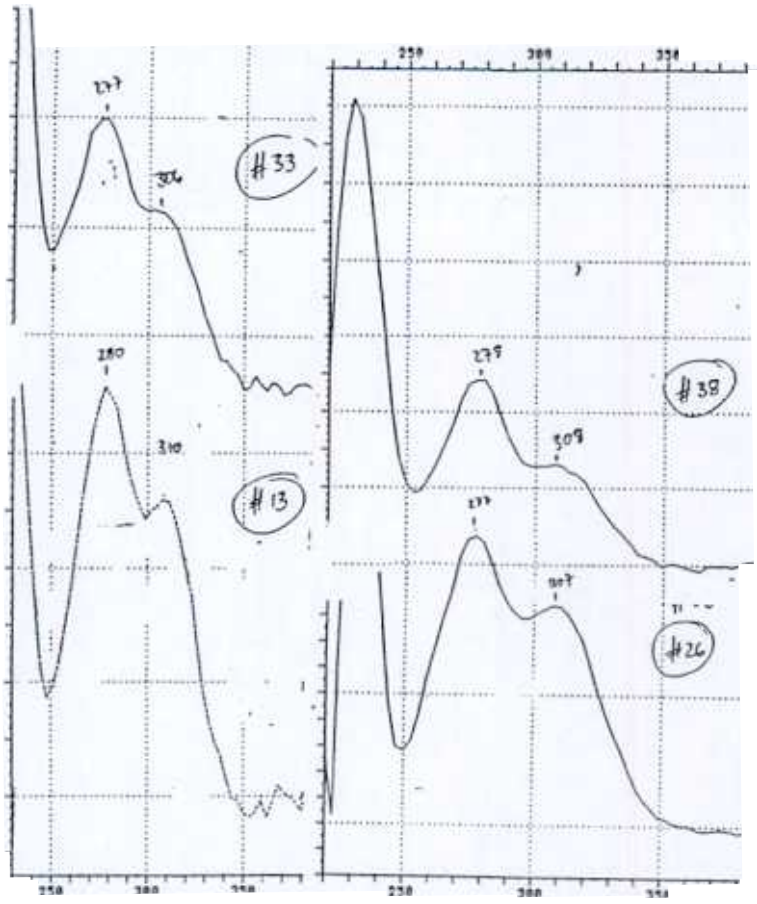


Fig 4



(m

Fi 5

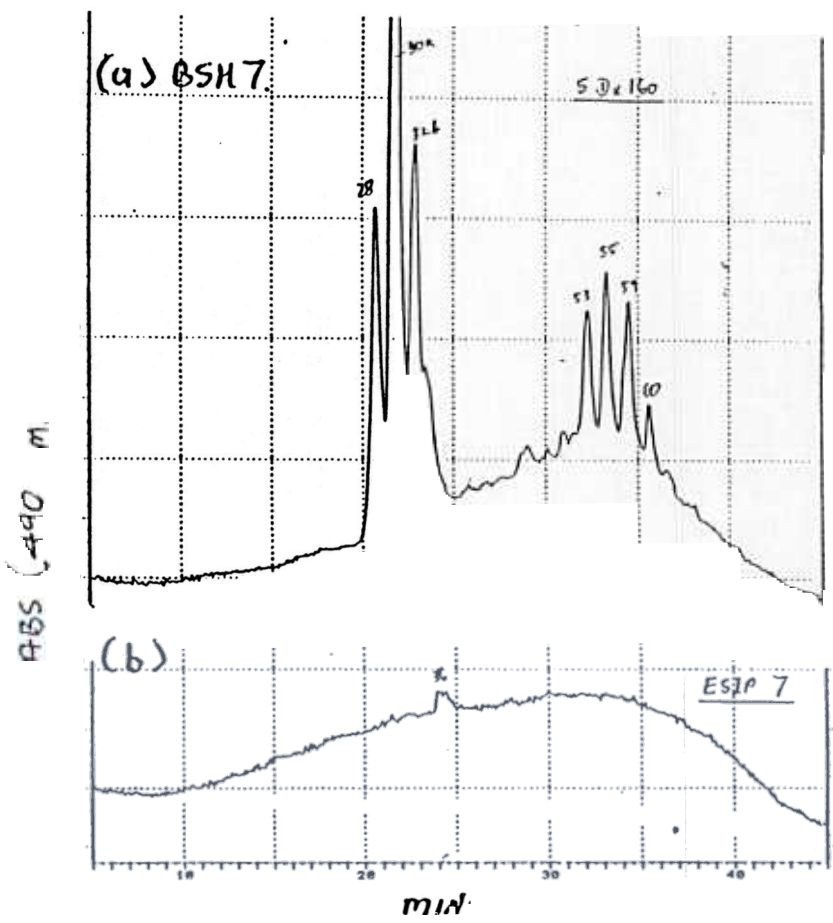
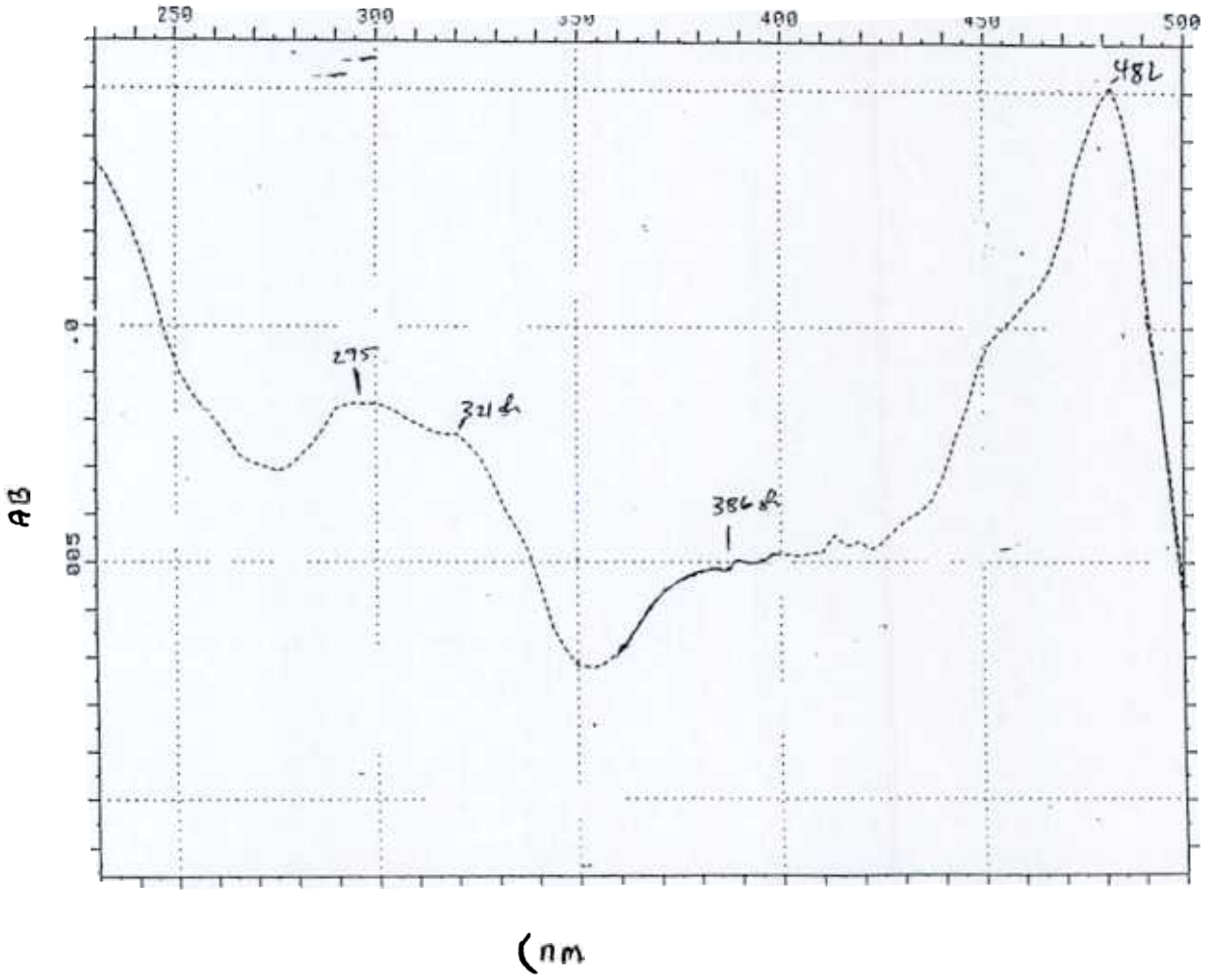
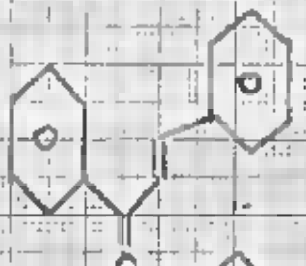


Fig. 6

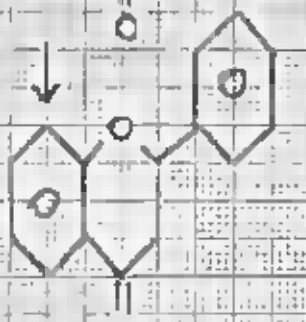


IG-7

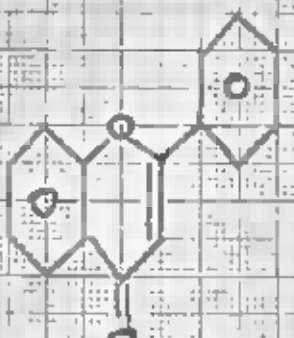
CINNAMIC ACIDS



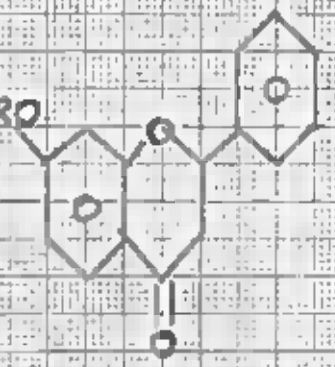
CHALCONES



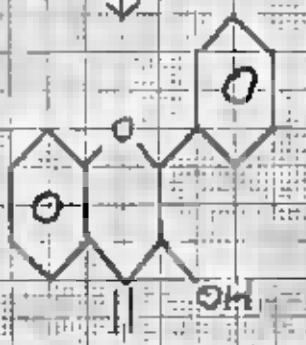
FLAVANONES



FLAVONES (in NBR-LS)

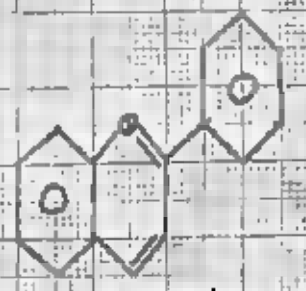


FLAVONE GLYCOSIDES (in NBR-LS)



DIHYDRO FLAVONOLS

CONDENSED TANNINS (in BR green)



3-DESOXY ANTHOCYANIDINS

BRITISH SOCIETY OF ANIMAL PRODUCTION

Title: THE USE OF HEAD SPACE GAS PRESSURE IN BATCH CULTURES TO AID IN THE DETERMINATION OF THE NUTRITIVE VALUE OF SORGHUM CROP RESIDUES

Name and address of author to present paper

M K Theodorou
AFRC - IGER
Hurley, Maidenhead, Berks, SL6 5LR, UK

Other author(s) and address(es)

B A Williams, A B McAllan
AFRC - IGER, Hurley, Maidenhead,
Berks, SL6 5LR, UK

Please tick as appropriate

Theatre		President's Prize	YES		BSAP	YES		Main author title: Prof		Dr		Mr	
Poster		Candidate	NO		Member	NO		Mrs		Miss		Ms	

This paper will describe a simple, yet sensitive rumen *in vitro* incubation technique where gas production is measured in time course experiments. Comparison of gas production curves and rates with different substrates allows an assessment of the nutritive value of a feed to rumen microbes. This system has been used to examine the digestion of different varieties of sorghum crop residues and the effects of phenolic compounds thereon, the data from which will be presented.

* * * Please see notes overleaf * * *

BRITISH SOCIETY OF ANIMAL PRODUCTION

Title: VARIATIONS IN THE PHENOLIC COMPONENTS OF SORGHUM CROP RESIDUES RELATED TO VARIETAL AND ENVIRONMENTAL DIFFERENCES

Name and address of author to present paper

I Mueller-Harvey
AFRC - IFR
Reading, Berks, RG2 9AT, UK

Other author(s) and address(es)

M S Dhanoa and A B McAllan
AFRC - IGER
Hurley, Maidenhead, Berks, SL6 5LR, UK

Please tick as appropriate

Theatre		President's Prize	YES		BSAP	YES		Main author title: Prof		Dr	
Poster		Candidate	NO		Member	NO		Mrs		Miss	

Environmental factors such as light, temperature, altitude as well as other stress factors such as water deficit and pest incidence may all contribute to the production of phenolic compounds in sorghum. Different varieties may respond differently under different environmental conditions and selection of particular varieties for particular conditions could result in residues of better nutritional quality.

Phenolic compounds in leaves and stems from different sorghum varieties grown at several sites were analysed by HPLC. The chromatograms were subjected to cluster analysis. Environment had greater

Whilst most varieties seemed to give strong environment x genotype interactions, the phenolic compositions

and non bird-resistant varieties were clearly expressed in leaf phenolics at some but not all sites. All varieties had similar stem phenolics.

This type of information is relevant to breeding programmes. A strategy is suggested for selecting BR-varieties with improved digestibilities.

• • • Please see notes overleaf • • •

Title: PHENOLIC COMPOUNDS AND THEIR RELATIONSHIP TO IN VITRO DIGESTIBILITY OF SORGHUM LEAVES OF BIRD RESISTANT AND NON-BIRD RESISTANT VARIETIES

Name and address of author to present paper

I Mueller-Harvey
AFRC - IFR
Reading, Berks, RG2 9AT, UK

Other author(s) and address(es)

J Reed, University of Wisconsin, Madison, USA.

A B McAllan,
AFRC - IGER, Hurley, Maidenhead, Berks, SL6 5LR, UK

Please tick as appropriate

Theatre / Poster		President's Prize Candidate	YES / NO		BSAP Member	YES / NO		Main author title: Prof / Mrs		Dr / Miss		Mr / Ms	

Sorghum stover is an important feed resource for ruminants in many developing countries and they are known to contain large amounts and a great diversity of phenolic compounds. It has been suggested that phenolic compounds inhibit the digestion of structural carbohydrates and could thus limit the nutritional value of the sorghum stover. Extracts of sorghum leaves and sheaths, sampled after grain harvest were examined and fingerprinted by post-HPLC column derivitisation.

The composition of phenolics was clearly different between leaf blades (LB) and sheaths (LS) in both bird-resistant (BR) and non bird-resistant (NBR) varieties. LS of bird BR- and NBR varieties were also different. *p*-Coumaric acid, apigenin and luteolin together with their 7-O-glucosides, butin and apigeninidin were identified. Derivatives of luteolinidin, chalcone and flavanone or dihydroflavonol together with several other derivatives of cinnamic acid, apigenin, luteolin, apigeninidin were also detected. Correlation analysis between HPLC peaks and *in vitro* digestibilities showed significant negative correlations with butin and several luteolin derivatives but not with apigenin derivatives.

* * * Please see notes overleaf * * *

BRITISH SOCIETY OF ANIMAL PRODUCTION

Title: EFFECTS OF HARVESTING AT DIFFERENT STAGES OF GROWTH AND LONG TERM STORAGE ON THE PHENOLIC COMPOISITION OF SORGHUM STOVER

Name and address of author to present paper

K Khazaal
AFRC - IGER
Hurley, Maidenhead, Berks SL6 5LR, UK

Other author(s) and address(es)

I Mueller-Harvey, A B McAllan
AFRC - IGER, Hurley, Maidenhead, Berks

E Osafo and E Owen, Reading University, Reading, Berks

A N Said, ILCA, PO Box 5689, Addis Ababa

Please tick as appropriate

Theatre	
Poster	

President's Prize Candidate	YES	
	NO	

BSAP Member	YES	
	NO	

Main author title

Prof		Dr		Mr	
Mrs		Miss		Ms	

Leaf stripping of sorghum for animal feeding during plant growth is common practice in some parts of Africa as is storing the stover for some months after harvesting before feeding. It is essential to know if either practice has any effect on the phenolic content of the plant and hence on nutritional quality. Phenolic compounds were analysed in leaf blade (LB) and leaf sheath (LS) fractions of two sorghum varieties harvested at three growth stages (50% flowering, black layer and maturity). Phenolic analysis was also carried out on the mature harvest samples of the two varieties plus two other varieties and also after storage for three months. There were obvious differences in the composition and content of phenolic compounds between LB and LS fractions of all varieties. Differences in the composition of phenolics between varieties were more apparent in LS fraction than in LB.

Harvesting at different growth stages was shown to have a large effect on the composition of the phenolic compounds between the 50% flowering stage and the black layer stage. No further changes occurred with increasing maturation.

Storage after harvest did not appear to influence the phenolic content or composition of either LS or LB.

* * * Please see notes overleaf * *

B12

BRITISH SOCIETY OF ANIMAL PRODUCTION

Preview of poster for Occasional Meeting Sept 2-4 1991

Title: SORGHUM STOVER AS RUMINANT FEED IN ETHIOPIA: EFFECT OF CULTIVAR, SITE OF GROWTH, PRE-HRVEST LEAF STRIPPING AND STORAGE ON YIELD AND MORPHOLOGY

Name and address of author to present paper

E L K Osafo
International Livestock Centre for Africa, PO Box 5689, Addis Ababa, Ethiopia

Other author(s) and address(es)

E Owen, Dept.Agric. Univ. of Reading, Earley Gate, PO Box 236 Reading RG6 2AT; A N Said, ILCA Addis Ababa; E M Gill, NRI, Central Av., Chatham; ME4 4TB A B McAllan, IGER, Hurley, Maidenhead SL6 5LR; Y Kabede, Institute of Agricultural Research, Nazret, Ethiopia

Please tick as appropriate

Theatre	
Poster	

President's Prize Candidate	YES	
	NO	

Fifteen varieties of sorghum, comprising bird-resitant and non bird-resistant varieties, were grown in 1990 at each of two contrasting sites (Debre Zeit: 1700 m, 700-900 rainfall; Nazret: 1500 m, 500-800 rainfall) and measurements made of grain and stover yield. Stover quality was mainly assessed by the content of leaf, sheath and stem. Within the above, two sub-experiments were undertaken. One measured the effect of pre-harvest stripping treatments - 5 lower leaves removed at 50% flowering, 3 lower leaves removed at 50% flowering and 2 removed at the 'black layer' stage or 5 lower leaves removed at black layer stage - compared to no stripping. The other trial measured the effect of post-grain-harvest storage treatments - stover stored *in situ* (standing in the field) or indoors for 2, 6 or 12 weeks after harvest - compared to stover at grain harvest. The results of the experiments will be presented and their implications discussed, particularly in relation husbandry practice and selective feeding by ruminants.

• • • Please see notes overleaf

B13

BRITISH SOCIETY OF ANIMAL PRODUCTION

Preview of poster for Occasional Meeting Sept 2-4 1991

Title:

FEEDING SORGHUM STOVER TO ETHIOPIAN SHEEP AND CATTLE: EFFECT OF CHOPPING AND AMOUNT OFFERED ON INTAKE AND SELECTION

Name and address of author to present paper

E L K Osafo
International Livestock Centre for Africa, PO Box 5689, Addis Ababa, Ethiopia

Other author(s) and address(es)

E Owen, Dept.Agric. Univ. of Reading, Earley Gate, PO Box 236 Reading RG6 2AT; A N Said, ILCA Addis Ababa; E M Gill, NRI, Central Av., Chatham; ME4 4TB
A B McAllan, IGER, Hurley, Maidenhead SL6 5LR

Please tick as appropriate

Theatre	
Poster	

President's Prize Candidate	YES	
	NO	

BSAP Member	YES	
	NO	

Main author title

Prof		Dr		Mr	
Mrs		Miss		Ms	

Two experiments will be reported, one with sheep and one with cattle. In Experiment 1 over 56 days [d], 48 rams (17 kg weight [M]), in 16 groups of 3, were offered long or chopped (Alvan Blanch Maxi Chaff Cutter) stover at 25 or 50 g stover/ kg M.d in a 2 x 2 factorial arrangement of treatments. Ram groups were supplemmented with 339 g DM/d of cottonseed cake and salt lick. Ram live-weight gain (g/d) was improved, both by chopping the stover ($P<0.05$; 43.2, 58.1, s.e. 3.98) and offering more ($P<0.001$; 38.2, 63.2, s.e. 3.98); stover form and amount offered did not interact. Stover intake (kg DM/group.d) was improved by both chopping the stover ($P<0.05$; 1.11, 1.34, s.e. 0.06) and offering more ($P<0.001$; 1.03, 1.42, 0.06); form and amount did not interact. Rams selected for leaf and sheath, and against stem. The proportion of offered stover left uneaten ranged from 0.11 (chopped 25) to 0.52 (long 50). Experiment 2, with 32 individually-fed cattle, involved the same treatments. The results of this trial are currently being processed and will be presented. The data will offer strategies for feeding stover to alleviate dry-season feed shortages and also generating residues for other purposes.

• • • Please see notes overleaf • • •

BRITISH SOCIETY OF ANIMAL PRODUCTION

Abstract for Occasional Meeting Sept 2-4 1991

Title:

FEEDING SORGHUM STOVER TO ETHIOPIAN GOATS AND SHEEP: EFFECT OF AMOUNT OFFERED ON INTAKE, SELECTION AND PERFORMANCE

Name and address of author to present paper

A A O Aboud
International Livestock Centre for Africa, PO Box 5689, Addis Ababa, Ethiopia

Other author(s) and address(es)

E Owen, Dept.Agric. Univ. of Reading, Earley Gate, PO Box 236 Reading RG6 2AT; J D Reed, Univ. of Wisconsin-Madison; A N Said, ILCA, Addis Ababa; A B McAllan, IGER, Hurley, Maidenhead

Please tick as appropriate

Theatre	
Poster	✓

President's Prize Candidate	YES	
	NO	

BSAP Member	YES	
	NO	

Main author title

Prof		Dr		Mr	
Mrs		Miss		Ms	

The experiment tested the hypothesis that intake of stover would increase, and hence performance, if the animals were offered increasing ad libitum amounts of stover, to facilitate selection. Twenty four bucks and 24 rams (weight [M], 16 kg) were fed individually on 150 g/d cottonseed cake and minerals, and offered 25, 50 or 75 g chopped sorghum (bird-resistant, Seredo) stover per kg M daily over 75 d. Live-weight gain (g/d) of rams was higher than bucks ($P<0.001$; 48.2, 21.5 s.e. 4.51); there was no interaction between species and amount offered. Growth rates increased with increasing amount of stover offered ($P<0.001$; 19.5, 39.8, 47.9, s.e. 5.84 . Stover intake (g DM/d) was higher for rams than bucks ($P<0.001$; 475, 428, s.e. 24.9) and there was no species x amount offered interaction. Stover intake increased with increasing amount of stover offered $P<0.001$; 315, 487, 563, s.e. 14.6). The proportion of uneaten stover increased with increasing amounts offered: rams, 0.05, 0.31,0.49; bucks, 0.16, 0.41, 0.53. The proportion of leaf and sheath in the uneaten stover decreased with decreasing amounts offered. It is concluded that both goats and sheep are capable of selective feeding leading to increased intake and growth when offered increasing amounts of chopped sorghum stover

• • • Please see notes overleaf • • •