SORGHUM BREEDING - A PROJECTION

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INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID
TROPICS, HYDERABAD

SUMMARY

I. Sorghum Breeding

The opportunity available to the sorghum program of ICRISAT has expanded substantially in the last year. Beside the station at Ouagadougou, Upper Volta, a sorghum breeder has been stationed at Wad Medani, Sudan, Ilonga, Tanzania, and it is anticipated that a sorghum breeder will be stationed within the ICRISAT program at Samaru, Nigeria. A program is also developing that will focus on the higher elevation situations primarily in Ethiopia and Kenya. ICRISAT has a sorghum breeder stationed at CIMMYT in Mexico; however this paper concentrates on India and Africa.

The Government of India has approved five locations as substations of ICRISAT: Bhavanisagar, Dharwar, Gwalior, Hissar, and a site yet to be selected in Jammu-Kashmir. How these locations might contribute to an ICRISAT cooperative network for sorghum breeding research is considered in this paper.

A second important development at ICRISAT is the increasing opportunities to screen sorghum for various traits of economic importance. Important criteria are:

1. Yield and stability
2. Quality
   - a) Traditional concepts
   - b) Food preparation and taste
   - c) Nutrition high lysine low tannin.
3. Resistance
   - a) Insects: stem borer, shootfly, Midge, possibly head bugs
   - b) Diseases: Grain moulds, Charcoal rot, Downy mildew
   - c) Drought
   - d) *Striga*.

The increasing capability to screen for these traits provides an ever improving base for effective cross discipline cooperation. An effort has been made in this paper to indicate how this multidisciplined approach would interact with the sorghum breeding program.

Indication has been made as to how the regional stations both within and outside of India could contribute to support the multidisciplined approach.

The program base is expanding to include material adapted to an array of climatic situations, and to incorporate some photosensitivity across the range of maturities. Some photosensitivity for the drier zones protects the cultivator who must repeatedly sow to establish stand, that he will have moisture at the end to mature his crop. A late sown photo-insensitive type might run out of moisture at the end of the season because it could be maturing after the rains had stopped. Some photosensitivity in late maturing types might well contribute to adaptation.

It is anticipated that each of the regional stations of ICRISAT outside of India will have its own research program and undertake service functions such as regional trials and nurseries. Breeders at these locations are looking to the center at Hyderabad for ever improving source material for factors as mentioned above. It is anticipated that the ICRISAT stations will truly form an effective network for crop improvement.

The important aspect of collection has not been stressed in this paper. It is recognized that the collection is a source of variability for the traits of interest. It has, is, and will be screened and evaluated for traits of concern. The introgression project is an important step between many collections and their use in the crop improvement program. The collection is recognized as an important source material.

It is anticipated that proven agronomically elite lines, showing weakness for one trait, will, whenever possible, be improved by a type of backcrossing program. This breeding procedure has not been mentioned in detail as it is reasonably straight-forward and specific. The breeding schemes presented are generalized and simplified in most cases.

The ICRISAT Regional Stations have been associated, in this paper, with environmental zones. These zones are useful for the evaluation of adaptation; however, it is recognized that breeding materials are useful across different zones. The comments made herein are not meant to imply a restriction on this movement but to help focus a concentration of effort.

This paper has been developed primarily within the sorghum breeding group at the Center (Hyderabad). It has been organized to serve as a base paper to generate interaction and comments. It is not considered a finished proposal. Your comments are most welcome.

February 1978. L.R. House

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SORGHUM IMPROVEMENT

APPROACH WITHIN SORGHUM BREEDING

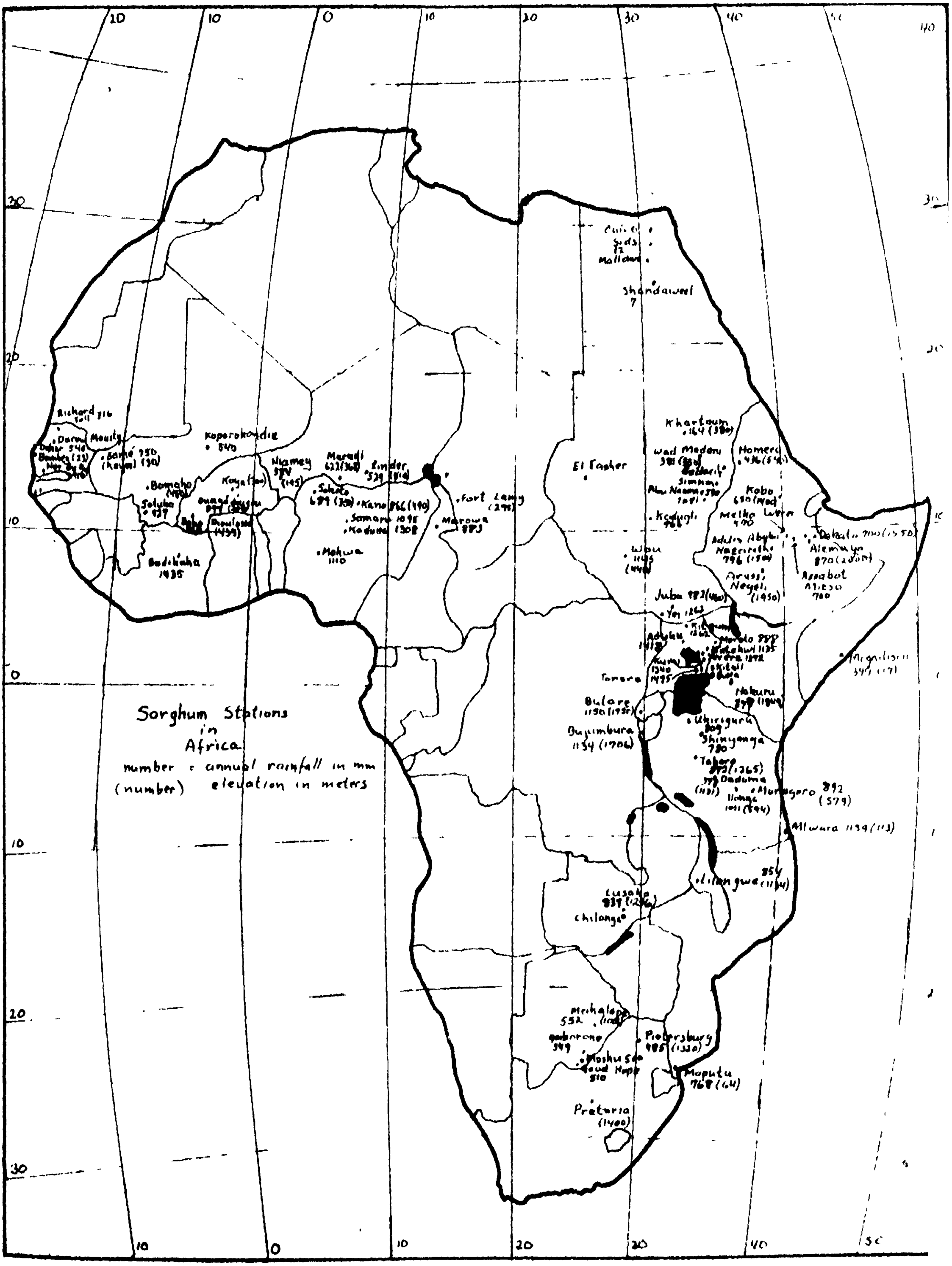
I. Introduction

The improvement of sorghum rests on across discipline approach. The problem is how to most effectively integrate the contributions from the disciplines. It is possible to improve several varieties for one or two particular traits and once these have been stabilized, cross with varieties stabilized for other traits. This building block approach is slow. Part of this paper presents an attempt to describe an approach to sorghum improvement in which promising breeding material is strengthened for all important traits during its development. Over time continually better varietal material should be forthcoming in terms of yield, resistance and quality traits. It should also be possible to more clearly focus on the problems of screening and to point to areas where greater effort and expanded facilities are required. This approach is also in keeping with the philosophy at ICRISAT; and, the desires of our cooperators, that we provide better and better source material.

This past year ICRISAT has had the opportunity to expand within and outside of India. The Government of India approved outreach locations at Bhavanisagar, Dharwar, Gwalior, Hissar, and a site in Jammu or Kashmir. Overseas, beside the program in Ouagadougou and Sotuba, programs began in the Sudan and Tanzania. Soon programs may open with likely centers at Samaru, Nigeria, and in the Ethiopia, Kenya area. ICRISAT has also taken responsibility for the cold tolerance program centered in Mexico. This represents a tremendous expansion of opportunity for ICRISAT's sorghum program. Each of the overseas regional stations has or will have its own program. It is expected that all centers will form a network of cooperating stations. As the stations are able, it is expected that they will be responsible for regional nurseries and trials as well as other activities such as collecting and germplasm maintenance, for their regions. Climatic differences exist and an attempt has been made in this paper to begin to describe these differences in terms of station relationships. There is particular interest in the relationship between the ICRISAT centers within India and those in Africa. This exercise should subsequently be expended for other locations of concern in the world. A map of Africa is presented showing the location of many sorghum stations there (Fig. 1).

II. Geographical and climatological relationships of ICRISAT stations in India and Africa

The network of ICRISAT stations has and is expanding considerably. It is important to attempt to analyze relationships between these locations for soil, climate, other environmental factors and the crop, and also, to consider the unique traits of each location with reference to contribution to the whole system. Cooperation between several interest areas at ICRISAT is obviously valuable.


Sorghum Stations
in
Africa
number = annual rainfall in mm
(number) elevation in meters
Richard Toll 316
Dakar 540
Mourdy
Koporokoudie
840
Bamako
(490)
Soluba
Niamey
(145)
Maradi
622 (368)
Zinder
Sokoto
Kano 866 (490)
Samaru 1095
Kaduna 1308
Fort Lamy
(295)
Marowa
893
Mokwa
1110
Bodikaha
1435
Kaya (300)
Boulosso
Cairo
Mallawi
Shandaweel
7
Khartoum
164 (380)
Wad Medani
Homera
El Fasher
Kobo
Kadugli
Melka Werer
Addis Ababa
Nazareth
796 (1500)
Alemaya
Arussi
Negeli
(1950)
Wau
1145
Juba
Yei 1262
Moroto
Adyuku
Kumi
1340
Tororo
1495
Nakuru
Bulore
1150 (1950)
Bujumbura
1134 (1706)
Ukiriguru
Shinyanga
780
Tabora
(1265)
Dodoma
Ilonga
Morogoro 892
(579)
Mlwara 1159 (113)
Lilongwe
854
Lusaka
837
Chilanga
Pietersburg
485 (1320)
Moshu
Good Hope
510
Maputo
768 (64)
Pretoria
(1400)
Mogadishu
10
10
0
10
20
30
40
40
30
20
10
0
10
20
30
10
0
10
20
30
40
50

i) The relationship between stations in India and Africa:

Geographical information about stations in India and in Africa with which they are climatologically most closely related is presented in Table 1. (It is assumed that Srinagar represents a climatological situation for the ICRISAT site in Jammu-Kashmir). Climatological information is presented in Table 2. Geographical information is presented for a number of stations in Africa in Table 3. It appears, for working purposes, that the climatic situation can be divided into eight categories:

1. The low rainfall zone
2. The intermediate rainfall zone
3. The high rainfall zone
4. The equatorial zone
5. The high elevation intermediate rainfall zone
6. The temperate zone
7. The East African zone
8. The Rabi Season, India.

An indication is made in Table 3 how each station might fit into this climatic division.

Weather records were used for the regional stations in India and for locations in Africa chosen to indicate broad climatological differences. These locations are not necessarily sorghum stations but are in areas where sorghum is an important crop. This information is presented in Figures 2 through 35. Graphical comparisons are made in

Tables 2 through 7 and climatological information on a station by station basis made in Tables 8 through 35; in fact, Tables 2 through 7 were made from the others.

The station at Hissar is most representative in India of the low rainfall zone (Figs. 2, 8, 10, 11, 12, 13). The rainfall is similar to that in the Sudan from Kassala south to Abu Naama. The rainfall at Hissar and Kassala is lower than at the West African locations. However, rainfed sorghum is taken on the road between Wad Medani and Gedariff (Figs. 2 and 11). With a station at Wad Medani, this would seem to be a good location in Africa to work on sorghums for the low rainfall zone. The temperatures at Hissar are definitely colder during the winter months, but during the growing season are hotter than at the African locations. The opportunity for supplemental irrigation at Hissar might help approximate the dry African situation. Hissar, then, would be a useful location for the sorghum program.

The climatic situation at Hyderabad is similar to that at Ouagadougou; Figs. 3, 16, 18, 20, 21, 22, 23, 33. The climatic situation across Africa from Roseires in the Sudan to Kano and Kayes is very similar to that at Ouagadougou. The dip in expeceted rainfall in August at Hyderabad is not expected at the other locations but the overall pattern is similar. Temperatures during the rainy season are very similar.

The rainfall and temperature patterns at Llongwe, Malawi, and Lusaka, Zambia, are cooler but close to those of the other stations in this zone. It would seem useful that regional activities from both Hyderabad, and Ouagadougou, as well as other stations in the zone, exchange seeds with these stations in the Southern Latitude.

The rainfall at Gwalior is higher than at Hyderabad (Figures 18 and 19) indicating that Gwalior might counterpart for a somewhat higher rainfall situation in Africa. However, the duration of rainfall is less (the season shorter), also, Gwalior is fairly far north (26° 14') which would present problems working with the photosensitive sorghums of the higher rainfall zones of Africa.

None of the regional stations in India have a climate similar to the high rainfall zones of Africa (Figs. 4, 26, 27, 28). This climatic zone will be best represented by the ICRISAT regional center developing at Samaru (Fig. 4). Breeding for this zone might also be undertaken at Sotuba in Mali. The total rainfall pattern in high elevation, high rainfall Ethiopia (Fig. 24) is similar to stations at lower elevation but the temperatures are very different. The need to service such areas needs to be considered in developing a program expected to center in Ethiopia and Kenya (Figs. 24 and 25 - note the similarity in rainfall pattern between Jimma and Kitali).

The rainfall pattern in the equatorial zone is best represented in India by the station at Bhavanisagar (Figs. 5, 32, 34, 35). The similarity in rainfall and temperature between Bhavanisagar and the ICRISAT regional center at Ilonga (near Morogoro) is good. Temperatures drop at higher elevations (particularly Butare) but still it seems reasonable to service this higher elevation area from the ICRISAT centers at Bhavanisagar and Ilonga. The rainfall pattern in this zone is different from those in the low, intermediate, and high rainfall zones in that the rain starts early in May and keeps increasing until October. Bhavanisagar is an important location to the sorghum program.

The climate of the high elevation intermediate rainfall zone of Ethiopia appears to be relatively similar to that of Dharwar (Figs. 6, 29, 31). The rainfall pattern at Nazareth is between that of Dharwar and Hyderabad (Figs. 6 and 18). Night temperatures at Harar are cooler ($5^{o}C$) and Dharwar is some 6^{o} of latitude further north. However, we should try and evaluate sorghums from the Ethiopian highlands at Dharwar in the Kharif to see if they give a near normal expression. If so, this would be useful to the sorghum program.

Srinagar is in a temperate climate with colder temperatures and low rainfall (Figs. 7, 15, 17) during the growing season. It is the only station in India which approximates many of the growing conditions of Southern Africa. Supplementary irrigation would be required, but with this we could evaluate materials of potential value for temperate

Southern Africa. Although not represented here, this location might relate well to growing conditions in the Near East. This station could counterpart with ICARDA should this become a regional station for the ICRISAT sorghum program. This station has potential value for the sorghum program.

The climate in East Africa is different from those so far described; there can be a distinctly bimodal rainfall pattern (Fig. 14), generally rather high rainfall (Figs. 24 and 25), and generally relatively high and cool. The program now proposed for Ethiopia and Kenya should be able to identify locations for appropriate testing. The idea of a center at Kitali is not bad, the rainfall is high and it is cool. The development of strong links to the Ethiopian Sorghum Improvement Program should also make possible useful sites for development and evaluation. The program now under consideration for Ethiopia and Kenya is for the high elevation cool situation. There are dry warmer, even hot, situations at lower elevations that may in time be reached (Fig. 14).

In summary, it is interesting and fortunate that there are such similarities in climate between the sites now available to ICRISAT in India and the regional station in Africa. These can be summarized as follows:

Low rainfall zone - Hissar, Wad Medani

Intermediate rainfall zone- Hyderabad, Ouagadougou

High rainfall zone	-	Samaru
Equatorial	-	Bhavanisagar, Ilonga
High elevation intermediate rainfall	-	Dharwar, Nazareth
Temperate	-	Srinagar
East African	-	Kitali and other locations in Kenya and in Ethiopia (in cooperation with the Ethiopian Sorghum Improvement Program)
Rabi	-	Hyderabad, Dharwar

This array of stations appears to provide working access to most of the climatic situations of interest. A high rainfall site in India, a temperate site in Africa, and opportunity for work for the hotter drier conditions of East Africa could be beneficial.

A better physical description of the environment in which sorghum grows would do much to help delineate zones and to relate these to the ICRISAT stations. It should also be possible to gain a better predictive base for the movement of varietal material from one location regionally. The possibility of cooperation of agroclimatology, soil physics and cereal physiology to describe in detail the environments and relate these to the growth of a standard set of lines including entries from all zones appears to be a reasonable approach.

Table 1: Geographic Information for ICRISAT Stations.

Station	Country	Zone	Elev.(M)	Latitude	Longitude
Hyderabad	India	Intermediate Rainfall, Rabi	545	17° 27'N	78° 28'E
Ouagadougou	Upper Volta	Intermediate Rainfall	308	12° 22'N	1° 31'W
Hissar	India	Low Rainfall	221	29° 10'N	75° 40'E
Wad Medani	Sudan	Low Rainfall	405	14° 23'N	33° 29'E
Bhavanisagar	India	Equatorial	278	11° 27'N	77° 30'E
Ilonga	Tanzania	Equatorial	594	6° 50'S	37° 00'E
Samaru	Nigeria	High Rainfall	686	11° 11'N	7° 38'E
Sotuba	Mali	High Rainfall		11° 12'N	8° 27'E
Dharwar	India	High Elevation Inter. Rainfall, Rabi	727	15° 27'N	75° 00'E
Nazareth	Ethiopia	High Elevation Inter. Rainfall	1500	8° 33'N	39° 17'E
Srinagar	India	Temperate	1586	34° 05'N	74° 50'E
Kitali	Kenya	East African	1895	1° N	35° E

Table 2: Rainfall Data (mm) for ICRISAT stations.

Station	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Hyderabad	1.7	11.4	13.4	24.1	30.0	107.4	165.0	146.9	163.3	70.8	24.9	5.5	764.0
Ouagadougou	0.0	2.0	13.0	16.0	83.0	122.0	203.0	280.0	144.0	33.0	1.0	0.0	897.0
Hissar	19.1	14.7	17.0	6.2	11.0	34.2	122.1	113.9	81.2	14.6	7.5	4.5	446.0
Wad Medani	0	0	0	3.0	15.0	33.0	130.0	129.0	55.1	15.0	1.0	0	381.2
Samaru	3	1.5	7.1	38.1	124.5	165.1	221.5	281.4	230.4	36.1	1.3	0	1117.3
Sotuba	0	0	0	5.1	48.0	180.0	333.0	253.0	213.1	51.1	6.1	0	1089.0
Bhavanisagar	11.3 (Jul)	12.2 (Aug)	21.8 (Sep)	50.8 (Oct)	94.0 (Nov)	41.7 (Dec)	52.0 (Jan)	90.8 (Feb)	108.1 (Mar)	171.9 (Apr)	116.9 (May)	35.1 (Jun)	806.7
Ilonga	6.1	13.0	15.0	32.0	89.9	132.1	122.9	124.0	176.0	209.0	78.0	13.0	1010.9
Dharwar	2.0	1.6	8.9	47.7	74.5	95.3	173.9	121.3	102.3	125.1	48.1	12.01	812.7
Nazareth	8.9	21.1	47.0	67.1	35.1	95.0	178.1	202.0	110.0	17.0	10.9	6.1	796.0
Srinagar	72.8	72.3	104.1	78.1	63.4	35.6	61.0	62.8	31.8	28.7	17.5	35.9	564.0
Kitali	20.1	38.1	71.1	147.3	165.1	132.1	160.0	170.2	106.7	73.7	58.4	40.6	1181.1

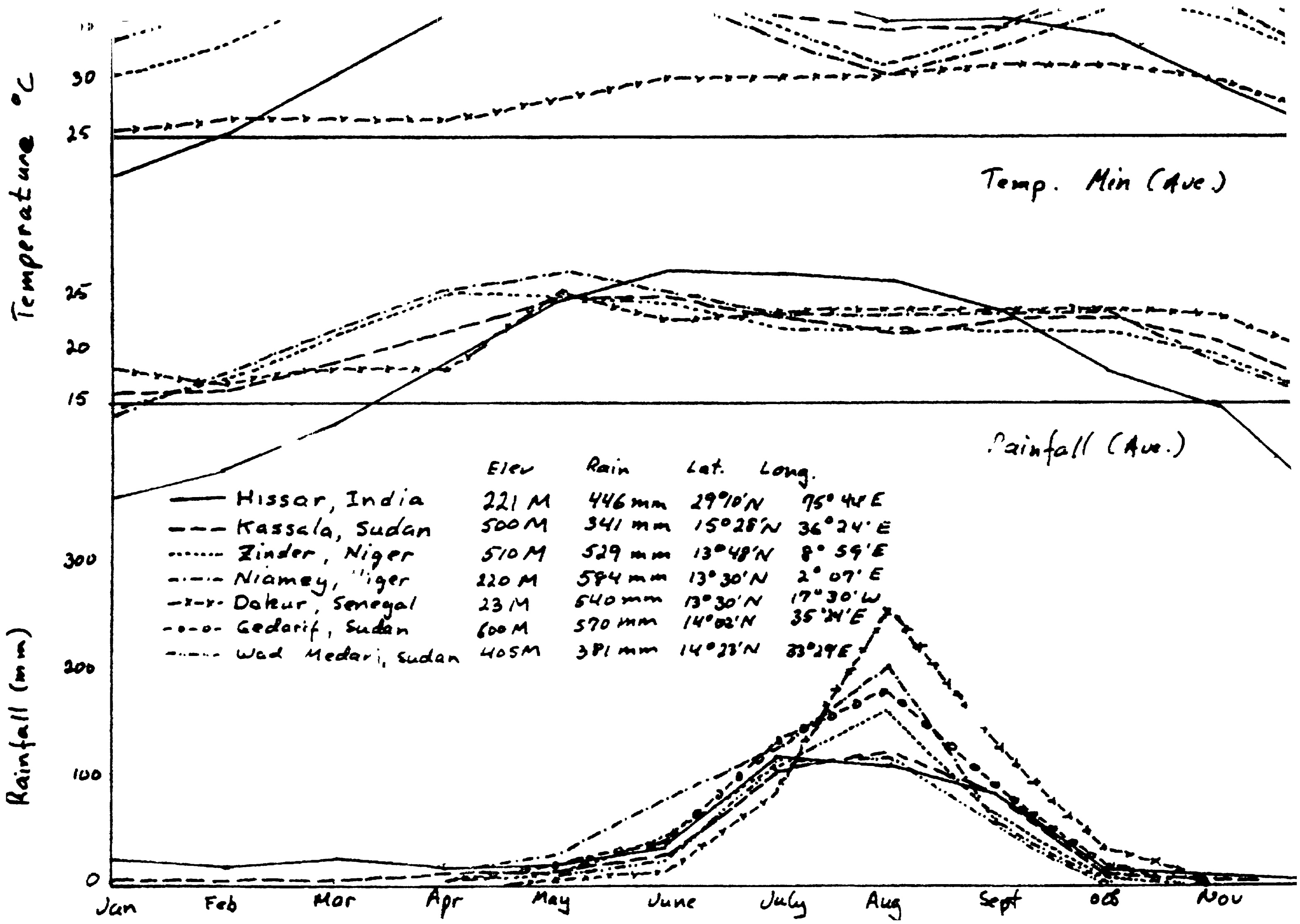
Table 3: Climatological and geographical information for some sorghum stations in Africa

Station	Country	Latitude	Longitude	Rainfall mm	Elevation meters	Climate (1)
Abu Naama	Sudan	13.09 N	33.57 E	590	430	LR
Aduku	Uganda	2.17 N	32.56 E	1418	1095	EA
Agadi	Sudan					
Alemaya	Ethiopia	12.25 N	35.34 E	870		HEIP
Arus Negele	Ethiopia	5.05 N	39 E			HLIR
Badikaha	Ivory Coast	9.27 N	5.38 E	1435	300	HR
Bambey	Senegal	14.42 N	16.27 W	632	20	LR
Bobo Dioulasso	Upper Volta	11.12 N	4.18 W	1181	432	HR
Bujumbura	Burundi	3.23 S	29.21 E	1139	1706	Trop, EA, HR
Butare	Rwanda	2.36 S	29.44 E	1150	1754	Trop, EA, HR
Chilanga	Zambia	15.5 S	29.1 E	775	1200	IR
Dodoma	Tanzania	6.10 S	35.46 E	578	1131	Trop, LR
Darou	Senegal	15.00 N	16.00 E	517	40	LR
Fanaye	Senegal					Temp, LR
Gaboronne	Botswana	24.40 S	25.55 E	540	983	Temp, LR
Good Hope	Botswana	25.28 S	25.26 E	510	1283	LR
Humera	Ethiopia	15.07 N	36.04 E	436	590	Trop.
Ilonga	Tanzania	6.50 S	37.00 E	1011	594	HR, Trop
Juba	Sudan	4.52 N	31.36 E	982	460	HR
Kaduna	Nigeria	10.36 N	7.27 E	1308	645	IR
Kadugli	Sudan	11.00 N	29.43 E	765	450	IR
Kamboinse	Upper Volta	12.22 N	1.31 W	852	308	IR
Kano	Nigeria	12.03 N	8.32 E	866	490	IR
Katakwi	Uganda	1.54 N	33.59 E	1135	1158	EA
Khartoum	Sudan	15.37 N	32.32 E	64	380	LR
Kitgum	Uganda	3.17 N	32.53 E	1262	914	EA, HR
Kobo	Ethiopia	11.49 N	39.36 E	650	1400	HEIR, LR
Koporo	Mali	14.30 N	4.12 W	540		LR

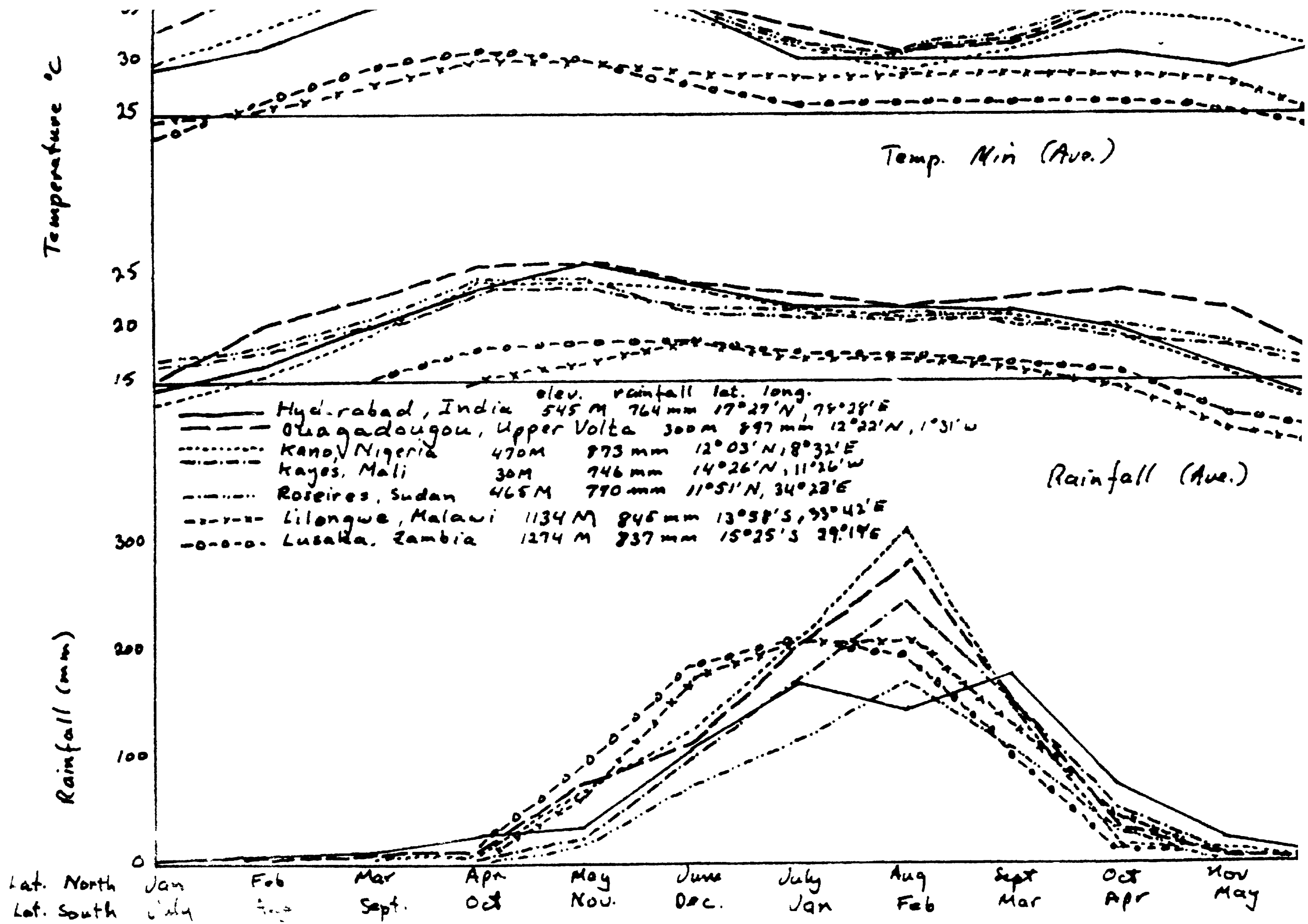
ıation	Country	Latitude	Longitude	Rainfall mm	Elevation meters	Climate (1)
ııl	Uganda	1.27 N	33.46 E	1340	1128	EA
›ıka	Zambia	15.25 S	29.19 E	837	1277	IR
halapc	Botswana	23.05 S	26.48 E	552	1006	Temp, LR
radi	Niger	13.28·N	7.06 E	622	269	LR
·rowa	Cameroon	10.26 N	14.19 E	883	404	IR
lka Werer	Ethiopia	8.59 N	40.10 E	570	916	LR
›kwa	Nigeria	9.04 N	5.59 E	1110	184	HR
›rogoro	Tanzania	6.51 S	37.40 E	892	520	Trop
·roto	Uganda	2.33 N	34.36 E	888	1524	EA
·shu	Botswana	24.26 S	26.09 E	500	945	Temo, LR
_nza	Tanzania	2.28 S	32.55 E	1002	1140	Trop
·zareth	Ethiopia	8.33 N	39.17 E	796	1500	HEIR
·kuru	Kenya	0.17 S	36.04 E	877	1849	EA, HEIR
·ioro du Rip	Senegal	13.44 N	15.49 W	916	18	HR, IR
lichard Toll	Senegal	16.5 N	15.5 W	316	7	LR
›aria	Upper Volta	12.5 N	2.5 W	837		IR
›ame	Mali	14.26 N	11.26 W	750	46	IR
›amaru	Nigeria	11.11 N	7.38 E	1095	686	HR
›hinyanga	Tanzania	3.33 S	33.24 E	780	1219	Trop
›imsim	Sudan	13 N	35.4 E			LR
›inthion Mdeme	Senegal	12.43 N	15.42 W	1387	15	HR
›utuba	Mali	11.12 N	8.27 W	927		HR, IR
'oboro	Tanzania	5.02 S	32.49 E	892	1265	Trop
'ororo	Uganda	0.42 N	34.10 E	1475	1233	EA
'ozi	Sudan	12.5 N	34. E			LR
kiriguru	Tanzania	2.42 S	33.01 E	809	1199	Trop
'ad Medani	Sudan	14.23 N	33.29 E	381	405	LR
'au	Sudan	7.42 N	28.01 E	1128	435	HR
ei	Sudan	4.01 N	31 E			HR

(1) See next page.

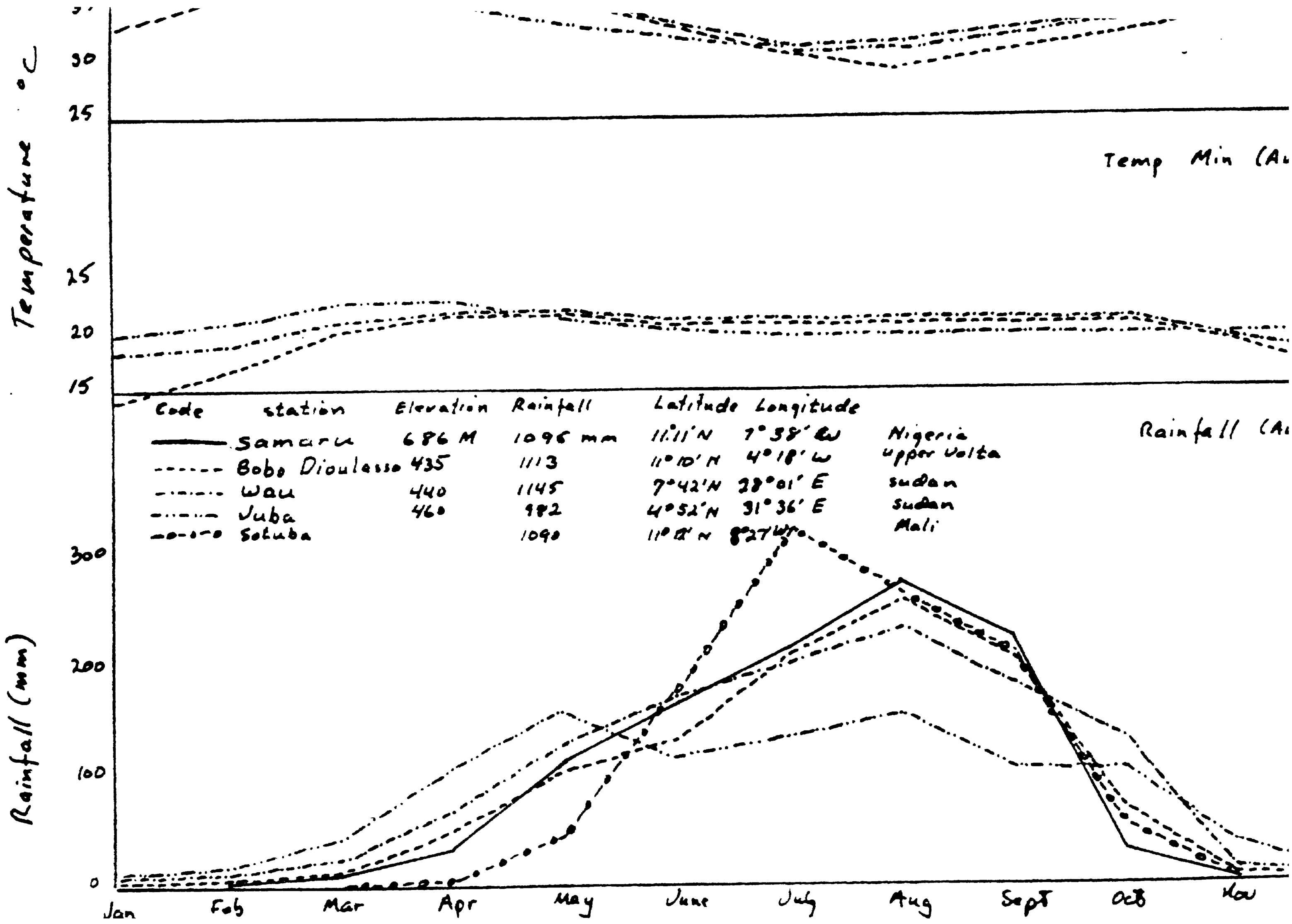
(1) Approximate climatic classification	ICRISAT Main Locations
The Low Rainfall Zone = LR	(Hissar)
The Intermediate Rainfall Zone = IT	(Hyderabad, Ouagadougou)
The High Rainfall Zone = HR	(Samaru)
The Equatorial Zone = Trop.	(Bhavanisagar, Ilonga)
The High Elevation Inter. Rainfall Zone = HEIR	(Dharwar, Nazareth)
The Temperate Zone = Temp.	(Srinagar)
The East African Zone = EA	(Kitali, Ethiopia ?)



Temperature °C
Temp. Min (Ave.)
Rainfall (Ave.)
Rainfall (mm)
Elev Rain Lat. Long.
Hissar, India 221 M 446 mm 29°10'N 75°48'E
Kassala, Sudan 500 M 341 mm 15°28'N 36°24'E
Zinder, Niger 510 M 529 mm 13°48'N 8°59'E
Niamey, Niger 220 M 594 mm 13°30'N 2°07'E
Dakur, Senegal 23 M 540 mm 13°30'N 17°30'W
Gedarif, Sudan 600 M 570 mm 14°02'N 35°24'E
Wad Medari, Sudan 405 M 381 mm 14°23'N 33°29'E
Jan Feb Mar Apr May June July Aug Sept Oct Nov



Temperature °C
30
25
Temp. Min (Ave.)
25
20
15
elev. rainfall lat. long.
Hyderabad, India 545 M 764 mm 17°27'N, 78°28'E
Ouagadougou, Upper Volta 300 m 897 mm 12°22'N, 1°31'W
Kano, Nigeria 470M 873 mm 12°03'N, 8°32'E
Kayes, Mali 30M 746 mm 14°26'N, 11°26'W
Roseires, Sudan 465M 770 mm 11°51'N, 34°23'E
Lilongwe, Malawi 1134 M 846 mm 13°58'S, 33°42'E
Lusaka, Zambia 1274 M 837 mm 15°25'S 28°19'E
Rainfall (Ave.)
Rainfall (mm)
300
200
100
0
Lat. North Jan Feb Mar Apr May June July Aug Sept Oct Nov
Lat. South July Sept. Oct Nov. Dec. Jan Feb Mar Apr May


Temperature °C
Temp Min (A
Rainfall (A
Rainfall (mm)
Code station Elevation Rainfall Latitude Longitude
Samaru 686 M 1096 mm 11°11'N 7°38'W Nigeria
Bobo Dioulasso 435 1113 11°10'N 4°18'W upper Volta
Wau 440 1145 7°42'N 28°01'E sudan
Juba 460 982 4°52'N 31°36'E sudan
Sotuba 1090 Mali
Jan Feb Mar Apr May June July Aug Sept Oct Nov