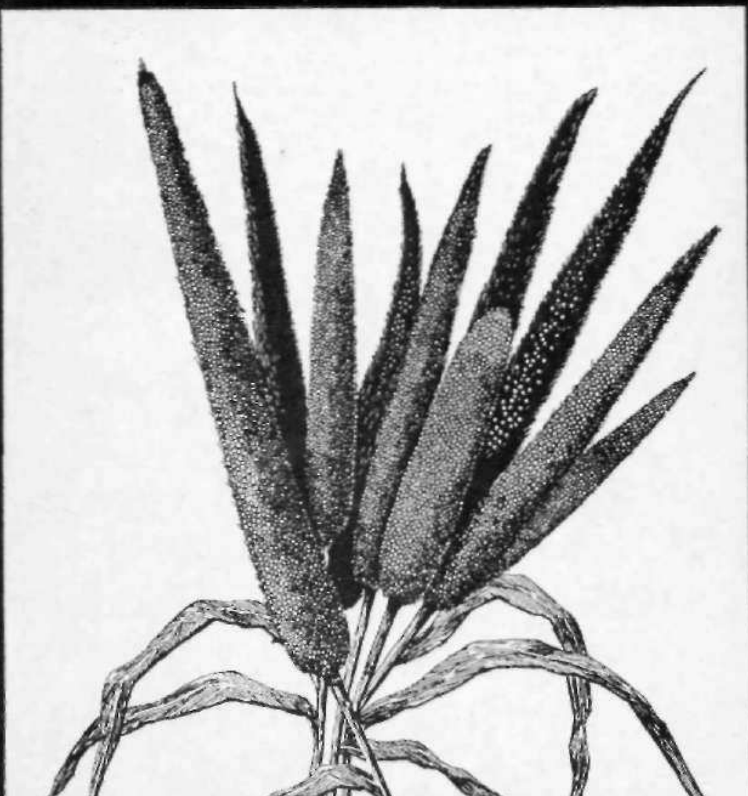
THE MILLETS

IMPORTANCE, UTILIZATION AND OUTLOOK



International Crops Research Institute
for the Semi-Arid Tropics
Hyderabad, India

THE MILLETS

IMPORTANCE, UTILIZATION AND OUTLOOK

K. O. RACHIE

INTERNATIONAL CROPS RESEARCH INSTITUTE
FOR THE SEMI-ARID TROPICS
1—11—256, Begumpet,
Hyderabad-500016, (A. P.) India.

CONTENTS

FOREWORD	iv
PREFACE	v
INTRODUCTION	1
DESCRIPTION	2
PROBLEM OF NOMENCLATURE	7
HISTORY AND GEOGRAPHIC ADAPTATION	9
China	10
India	11
Russia	12
Western Asia	12
Africa	12
Eastern Europe	13
United States	13
WORLD PRODUCTION OF MILLETS	14
Asia and Africa	17
Production Trends	20
UTILIZATION OF MILLETS	23
Comparison of Nutritive Values - Grain	24
Proximate Principles	24
Minerals	25
Vitamins	26
Lipids	26

Proteins 26
Feeding Trials 27
Loss in Milling 29
Composition of Forage 29
Industrial Uses 30
OUTLOOK FOR MILLETS 30
BIBLIOGRAPHY
Section I - Text References 34
Section II - Sources for Biochemical Analyses 37
APPENDICES
Appendix 1 40
Appendix 2 41
Appendix 3 42
Appendix 4 44
Appendix 5 47
Appendix 6 48
Appendix 7 49
Appendix 8 50
Appendix 9 51
Appendix 10 53
Appendix 11 54
Appendix 12 55
Appendix 13 56
Appendix 14 59
Appendix 15 60

FOREWORD

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is pleased to publish this bulletin as a service to scientists, students and agriculturists concerned with the improvement of cereals and farming systems throughout Asia, Africa and Latin America. The genetic improvement of pearl millet is one of ICRISAT's major projects and — along with several other millets - figures prominently in our research program on farming systems.

However, no single institute working alone can bring about the yield increases so vitally needed in these drought-resistant cereals. We are publishing this bulletin with the aim of supporting the many other researchers and extension specialists who will play an important role in the international effort to increase the agricultural productivity of semi-arid regions.

The history of this publication involves the contributions of many specialists who have given their time in a similar spirit of international collaboration. Dr. Rachie undertook the research and wrote the original monograph under the sponsorship of the Rockefeller Foundation. ICRISAT Associate Plant Breeder J.V.Majmudar and R.P.Jain, S.C.Gupta and K. Anand Kumar, research associates in ICRISAT's Pearl Millet breeding program, updated the bulletin with the most current statistical information available. We commend the foresight of those who initiated the project and are gratified that ICRISAT has had the opportunity to make a contribution towards its completion.

Dr. R. W. Cummings, director
International Crops Research Institute
for the Semi-Arid Tropics
Hyderabad, India. 1975

PREFACE

The impending world food shortage, particularly in developing countries of the tropics and subtropics of Asia, Africa and the Americas, implicates the cereals as the most efficient vehicle for producing the greatest amount of near-balanced food for human beings. Modern biological and agricultural science has made tremendous progress in increasing and stabilizing cereal productivity, particularly of the species like rice, the small grains and maize — the preferred foods of developed nations having the technology and resources to undertake their improvement in depth. The spectacular successes of these efforts are beginning to shift the role of cereals from that of extensive cultivation on good to marginal lands to intensive cultivation competitive with most of the "cash" crops. However, surpluses and the resulting apathy in cereal improvement is shifting the leading centers of improvement from advanced nations to regions/ countries like Mexico, Philippines and India, where food production is still critical and vital to the total economy.

The crops -- rice, wheat and maize -- although receiving the major attention and resources in total cereal improvement in the world, do not necessarily meet all requirements, are the most nutritious nor produce the greatest amount of food on a unit of land/time/nutrients/ water basis. In fact, millets and sorghum together may constitute the most important cereal food source after rice in the tropical developing nations-- particularly in the arid and semi-arid tropics and subtropics. Moreover, prospects are excellent for increasing the production of millets relative to expanding the use and productivity of marginal lands. Multiple cropping schemes, improvement of nutritive qualities, the need for specific adaptive features, and the drive for economy of production per unit of input and time are also factors of importance.

Recognizing the potential and future importance of millets, the Rockefeller Foundation has undertaken the assembly of the world's literature on these crops comprising as many as 14 species in the form of bibliographies and as a comprehensive monograph. These are intended to serve the needs of scientists, students, crop specialists and other workers concerned with the improvement, technology and production of the millets and other miscellaneous cereals. This compilation is based on a range of actual experience on the millets over several years and an extended survey of the literature. The latter was obtained from a broad array of sources covering the major period of formal documentation of crop technology and research starting in late nineteenth century to the present. Physical limitations obviate the detailing of techniques and less pertinent facts or findings; but rather an attempt is made to present findings and information as it contributes to knowledge of the crop as a plant, and how it is used and cultivated. For more-detailed information on related subjects, experimental procedures, and other descriptive matter, the reader is referred to the comprehensive lists of references provided in the bibliographies of the world literature on "The Millets"-- the first volume of which was published by The Scarecrow Press, Inc., Metuchen, N.J.IBSCP, 1967).

This monograph was initiated at the suggestion of Dr. Sterling Wortman, Director for Agricultural Sciences (Rockefeller Foundation, New York). The excellent libraries and other facilities provided by the Universities of California (Davis) and Nebraska through their respective Agronomy Departments have been utilized for the major effort in collecting and assembling the information comprising this monograph. Several persons have contributed valuable assistance in helping assemble information, reviewing the manuscript, and making valuable comments on the content and form of the manuscript:

Dr. D.G.Hanway - Chairman, Department of Agronomy, University of Nebraska, Lincoln, Nebraska.

Dr. G.W. Burton - Principal Agronomist -- ARS: Coastal Plain Experimental Station, Tifton, Georgia.

Mrs. Virginia Piening - Secretary, Lincoln, Nebraska.

To all involved and contributing to this work, deep appreciation is hereby extended.

K. 0. Rachie

THE MILLETS

IMPORTANCE, UTILIZATION AND OUTLOOK

K. O. Rachie[1]

INTRODUCTION

The term "Millets" refers to any of the small-seeded cereal and forage grasses used for food, feed or forage. In earlier times sorghum and even maize were included in this category. Synonyms like "miscellaneous cereals" or "coarse grains" are also used to describe the millets. However, with increased use and advances in improvement, first maize and later sorghums received separate status; although in many regions of the world, crop production statistics are still reported as a total for the millets and sorghum. It is likely that other millet species will gain separate status as they begin receiving increased attention in improvement and are more extensively used.

Generalizing on the common characteristics and utilization of the fourteen species of millets and miscellaneous cereals can be somewhat misleading. However, it might seem desirable to justify this categorization. The following statements may be considered applicable to one or more millets at this time:

1. Millets are small-seeded, annual cereal grasses used for food, feed, forage, industrial or other products in tropical or temperate regions. Miscellaneous cereals include species of Eragrostis, Digitaria and Coix not ordinarily considered millets, but which are somewhat restricted in use and otherwise fit this description .

'Associate Director General of Research, International Center of Tropical Agriculture (CIAT), Cali, Colombia

2. They are frequently short-term, warm-season (summer) crops sometimes used in emergencies following crop failure from some unfavorable weather conditions or other calamities.
3. Individual millet species or varieties frequently possess some unusual characters for adaptation or use, like tolerance or resistance to drouth, high temperatures, low soil fertility and diseases or pests; or for making special foods or beverages.
4. The millets have received very little attention as regards their improvement, notwithstanding their relative importance and future potential for increasing food production in both the developing and developed regions of the world.

These generalizations may not apply in the future as research explores utilization, growing conditions and response to management factors; and begins improving plant types and solving pest problems.

DESCRIPTION

The term "millets and minor cereals" are considered to embrace ten genera and at least fourteen species, all of which are members of the grass family Gramineae. These are listed below together with the most widely used common and scientific epithets:

Common	Scientific
1. Bajra, pearl or bulrush **millet**	*Pennisetum typhoides* Stapf and Hubb
2. Italian or **foxtail** millet	*Set aria italica* Beauv
3. Proso or common millet	*Pan/cum miliaceum* Linn
4- Little millet	*Pan/cum miliare* Lam
5. Ragi or finger millet	*Eleusine coracana* Gaertn
6. **Koda or ditch millet**	*Paspalum scrobiculatum* Linn

	Common	Scientific
7.	Japanese barnyard millet	*Echinocloa frumentacea* (Roxb.) Link.
8.	Jungle rice or shama millet	*Echinocloa colona* (L.) Link
9.	Australian millet	*Echinocloa decompositum*
10.	Browntop millet	*Brachiaria(Panicum)ramosa* (Linn.) Stapf
11.	Teff	*Eragrostis tef* (Zucc) Trotter
12.	Fonio or hungry rice	*Digitaria iburua* Stapf
13.	Fonio or hungry rice	*Digitaria exilis* Stapf
14.	Adlay or Job's tears	*Coix lachryma-jobi* Linn

Two subfamilies and four tribes encompass the ten genera and fourteen species considered to comprise "millets and minor cereals" as shown in the taxonomic scheme presented in Appendix 1 (after Stebbins and Crampton 1961). Other taxonomic descriptions are given of the genera *Eragrostis, Eleusine. Panicum, Echinocloa. Digitaria, Paspalum. Setaria, Pennisetum* and *Sorghum* by Mansfield (1952). The tribe Paniceae with seven genera and eleven species includes five of the most important millets -- Pearl, Italian, proso, Japanese and koda millets in addition to sorghum the "great millet". Other economically important species are *Eleusine Coracana* and *Eragrostis tef* in the tribe Chlorideae. Leonard and Martin (1963) have grouped the cereals and some of the millets on the basis of certain botanical characters and provided a taxonomic key for their identification as reproduced in Appendix 2 and 3. Hector (1936) separates the Setarias, Pennisetums, and Eleusines from the Panicums and Echinocloas on the basis of spicate inflorescence having an involucre of bristles below each spikelet, as contrasted with a paniculate inflorescence without an involucre, as described below:

A. Inflorescence spicate. Involucre of bristles below each spikelet.

B. Spikes simple.

C. Spikes loose, grains enclosed in lemma and palea at maturity. . . Foxtail millet
{Setaria italica. Beau v.)

CC. Spikes dense; grains becoming free of lemma and palea at maturity ... ... Pearl Millet
(Pennisetum typhoides, Stapf and Hubbard.)

BB. Spikes more or less digitate . . . Finger Millet
(Eleusine coracana, Gaertn.)

AA. Inflorescence paniculate. No involucre below each spikelet.

B. Inflorescence a drooping panicle.

No awns . . . Broom-Corn, or Proso-Millet
(Panicum miliaceum L.)

BB. Inflorescence a raceme of short spikes, awned . . . Japanese Barnyard Millet
(Echinochloa frumentacea. Link.)

Pearl millet is undoubtedly the most important and has the greatest potential of all millets. It is probably the most drouth and heat tolerant of all cereals being associated with high temperatures, light soils and semi-arid growing conditions. Nevertheless, it responds spectacularly to good management and possesses a basic plant architecture — including cylindrical -- or conical-shaped spikes of varying length, thickness and condensation -- with exceptional potential for grain as well as fodder production. Ease of manipulating or restricting crossing, effecting natural cross pollination (through protogyny); the existence of two cross-compatible cytogenic male sterility mechanisms; **and** the availability of an extensive range of genetic diversity in the world diploid (2N=14) collection of 2700 **stocks make it** highly amenable to improvement by breeding.

The important areas of production are the hot, dry plains of Southern Asia, and the southern periphery of the African Sahara.

Foxtail or Italian millet may well have unrealized potential for grain production. The Chinese claim exceptionally high yields sometimes exceeding 11,000 kg per ha. It is drought-resistant, grows at higher elevations (up to 600 feet) and is frequently sown as an alternate crop with sorghum on black cotton soils when rainfall is deficient. It also grows well on loamy or alluvial and clayey soils. Extensive diversity is available in the 660 world collection entries maintained in India. China grows most of the world's crop, but some Italian millet is grown in India, Japan, and Russia. In the U .S.A. it is largely sown for fodder.

Common or proso millet is a relatively short-duration emergency or quick-season irrigated crop with low moisture requirements. The grain after hulling makes a nutritious and palatable cereal for unleavened bread or cooked. This millet was grown in Russia, China, the Balkan countries and Northern India in historical times, being later replaced by rice and other cereals.

Little millet appears related to proso but is generally shorter, has smaller panicles and seeds, and is grown on a limited scale voluntarily or with minimum care on poor lands. Little millet matures quickly and withstands both drouth and waterlogging. Less genetic diversity occurs in the world collections of this species than appears among the other species. Perhaps very little of this species is grown outside of India.

Finger millet or ragi has a relatively wide range of adaptation within moderate temperatures and moisture ranges. It is most widely cultivated on hilly, lateritic soils in the 20-40 inch rainfall belt of the tropics and sub-tropica! regions. It has high-yielding potential producing highest mean yield among the millets in India, and is frequently grown both dry and irrigated on lands where moisture is insufficient for rice. The grain is very nutritious, and has malting properties. Ragi is highly selfpollinated, has 36 or 72 (2N) chromosomes, and the world collection of about 1000 entries includes a wide range of plant andearheadtypes, grain qualities, disease resistance maturities and lodging resistance.Intermediate elevations in South Central India and East Africa are the principal producing regions. The foothills of the Himalayas, Sri Lanka, and Malaysia grow limited quantities of this cereal.

Kodo millet is rather extensively grown on the poorest of soils throughout India but is probably not cultivated to any extent elsewhere. It is reputed to be extremely hardy, drouth resistant and grows on stony or gravelly soils which would not support other crops. It is relatively long in duration requiring five or six months to mature compared with two to four months for the other m i l lets.

Japanese and Shama millets are vigorous and have a wide adaptation in terms of soil and moisture requirements. They grow well in different seasons and at higher elevations, but require three to four months for maturation. It is grown for both grain and fodder in India, Eastern Asia and parts of Africa, and in the Eastern U S A it has been a valuable forage crop. A relative, Australian millet *(Echinocloa decompositum),* is used by the aborigines of that continent as a cereal grain (Matz 1959).

Browntop millet, a native of India, has relatively limited cultivation. In the United States as much as 100,000 acres are grown annually chiefly in Georgia, Florida and Alabama for hay and pasture; while the seed provides feed for quail, doves and other game birds. As a fodder crop it is finer-stemmed and quicker-growing than pearl millet with which it is associated.

Teff is a high-elevation (up to 2700 meters) cereal confined largely to the highlands of Ethiopia. It is a short growing lovegrass, highly self-fertilized, bearing tiny seeds, and extremely difficult to cross. About 150 collections of the crop are available at Debre Zeit (near Addis Ababa) and Purdue University. Investigations on this species have been done mainly in Ethiopia.

Fonio *(Digitaria* species) is cultivated to a limited extent mostly in West Africa on intermediate elevations or plateaus having somewhat more favorable rainfall and heavier soils than the surrounding savannah. The nutritive quality of fonio grain is quite high from analysis of protein fractions by Lanza *et al* (1962).

Adlay or Job's tears, a member of the tribe Maydeae, has been grown to limited extent in the Philippines, Zaire and South America as a cereal. These are thin-hulled types and are reported to have exceptional nutrition qualities. Thick-hulled strains are used as ornamentals in Africa, the United States and other regions.

PROBLEM OF NOMENCLATURE

There is a major problem in communication on the millets. The origin of the term 'mil' or 'millet' has reference to high number, probably implying many grains may be produced from growing a single seed. It also implies small seeds but the species covered may range from very tiny such as *Eragrostis tef* where the weight of 1000 seeds is as low as 0.14 grams to the larger *Pennisetum typhoides* seeds with a 1000 seed weight sometimes exceeding 15 grams. The term millet often refers to a different species in different regions. Most frequently it applies to *Pennisetum typhoides, Panicum miliaceum, Setaria italica* or *Eleusine coracana.* It may also be used in reference to *Echinoclua frumentacea* (or *E. co/onum, E. crusgalli,* and *E. decomposition) Paspalum scrobiculatum, Panicum miliare, Brachiaria ramosum. Eragrostis tef,* and *Digitaria exilis* or *D. iburua* It has been used in association with maize, and is still occasionally given as an inclusive term covering sorghum -- the "great millet". Thus, it can embrace two sub-families, four tribes, ten genera and fourteen species.

The term "millet" is sometimes used with a descriptive adjective helping identify the species such as pearl, bulrush, finger, Italian, common or Japanese. Often it is used alone without identifying the species even by scientific workers whose publications receive world-wide distribution. Some investigators may use different names for the same species (like Pennisetum, bajra, pearl, bulrush or cattail millet) in the same conversation, communication or publication. Unfortunately, this situation prevails in several other languages besides English, although in many regions and countries, particularly where a millet species is a major crop, a single term such as *Bajra* in India or *Proso* in the U.S.S.R. is becoming universally accepted.

Much of the present confusion related to common nomenclature could be resolved amongst the English-speaking workers and literature if (1) the species were identified by its scientific name (and authority) at least once in each article or communication, and (2) a single common name for each species was universally accepted and used. In an attempt to begin standardizing the nomenclature of millets the following proposals are made: (1) drop the term "millets" as a catch-all for several crops and adopt one of the more appropriate descriptive terms like "Miscellaneous, Small-seeded, Other Cereals", or "Annual Fodder Grasses"; (2) apply a simple, few-syllable term for each species. The latter proposal might involve one of the following names for each species:

	Possible Common Names	
Scientific Name	Preferred	Others
1. *Pennisetum typhoides*	Millet or Mil*	Pennisetum Pearl, Bulrush, cattail or Bajra (Hindi)
2. *Eleusine coracana*	Ragi	Eleusine, Finger Birdsfoot
3. *Panicum miliaceum*	Proso	Common, French, Hog, Miliaceum, or Panicum

"The adoption of the term "millet" or "mil" for Pennisetum would preclude its use for other species .

Scientific Name	Possible Common Names: Preferred	Others
4. *Setaria italica*	Setaria	Foxtail, Italian
5. *Paspalum scrobiculatum*	Kodo	Paspalum, Ditch
6. *Echinocloa crusgalli* or *E. colonum*	Echinocloa	Shama,JaDanese Billion Dollar
7. *Panicum miliare*	Miliare	Little, Panicum
8. *Brachiaria ramosum*	Browntop	Brachiaria
9. *Digitaria exilis, D. iburua*	Fonio	Hungry rice
10. *Coix lachryma-jobi*	Adlay	Job's Tears, Coix

HISTORY AND GEOGRAPHIC ADAPTATION

Millets were consumed as cereals and brewed from prehistoric times in Asia, Africa and Europe. They may have been among the first cultivated crops being grown in the "Hoe Age" preceding the "Plow Age". The millets were widely grown in Europe during the Middle Ages being one of the principal foods of the poorer people of Rome and of Europe generally. During the nineteenth century, however, the millets were gradually superseded by wheaty rye, rice, maize and potatoes in Europe owing, in part, to the increased popularity and use of raised bread and to some extent by increasing the substitution of cereals by potatoes and other vegetables. However, the production and consumption of millets has persisted to a greater extent in Eastern Europe and Russia, where they are still used in certain parts for cooking, baking, brewing or for other purposes. Production of millets in the Americas and

Oceania has largely been restricted to limited special uses as an emergency grain crop, for fodder and birdfeed. The small size of millets seeds relative to the mature plant size (compared with other cereals and maize) with corresponding low seed requirements and the ability of several species to produce more grain than other cereals under conditions of intense heat, scanty rainfall, short seasons, and medium soil fertility levels are important advantages for both multiple cropping and the growing of emergency or catch crops.

The world's millet crop is grown largely in China, India, Russia and several African countries along the southern fringe of the Sahara and in the eastern part of that continent. Very little of the produce enters trade channels, but is largely consumed locally. China and India together produce about half the world's millet crop according to FAO (1968) estimates. Russia ranks third in production and together with the ten other countries from Iran eastward comprising the great millet growing region of Central and Eastern Asia contributes about 65% of the world's crop. These and other important growing regions were described by Anderson (1948) and are briefly discussed below:

China

Foxtail millet is by far the most important species being grown in Hopei, Shantung, Horan and Shansi provinces and generally in Northern China. Foxtail millet grows both in mountainous as well as the plains regions of China. Millets are frequently consumed with edible legumes like soybeans and sometimes sprouted to improve nutritive qualities.

Proso or bread millet, the second most important millet in China, is grown principally in the provinces of Shantung, Hopei, Shansi and Kansu. Sometimes it is used for making wine or beer.

Finger millet is not extensively grown, but occurs mainly in Shantung, Shansi and Szechwan. It is most often used in beer making for which it is well suited.

India

Cattail, pearl or bulrush millet or "bajra" is the most important millet in India. It may be substituted for sorghum in some areas if the monsoon is light, but otherwise is extensively grown in the dry western region of the country— principally Rajasthan, Maharashtra, Gujarat and Punjab. Another region is the Eastern side of the Western Ghats and in Tamil Nadu where it may even be sown as a winter crop.

Finger millet or ragi is grown mainly in the South in Karnataka and Tamil Nadu where approximately two-thirds of the two-million-ton annual crop is produced. It appears to thrive on damp, steep slopes or mid-elevation plains in the same climate in which rice thrives. It is also grown in the lower to intermediate elevations of the Himalayas. Sometimes it is grown as an irrigated crop in the dry season of South India. Sometimes it is intersown between rows of maize or other crops. Ragi may also be transplanted from irrigated beds sown in May in Southern India. In Gujarat it is sown on alluvial soil and irrigated with flood water, and frequently eaten as a green vegetable by cooking or roasting the green seeds. Most of the millet crop is grown on the eastern slope of the Ghats up to the edge of the Deccan plains, while rice predominates on the wetter western slopes of the Ghats. The somewhat damper climate of the south is particularly favorable for this species and, if irrigation is available, ragi may be grown in any season.

Foxtail millet grain is prized as a food, considered a 'holy' dish for religious ceremonies or festivals, and is frequently prescribed in the diet of invalids or pregnant women. Foxtail grows in dry climates but requires good soils. Although not extensively grown, it is an important crop in certain sections of the lower Deccan plains and highlands of Andhra Pradesh, Karnataka and Tamil Nadu.

Proso millet is grown mostly in Southern India, south of the Krishna River, although it may be cultivated in scattered locales in central and hilly tracts of the North.

Other millets are scattered throughout the country. Paspalum (kodo millet) may be cultivated in stony or gravelly, poor soils and requires a long season to mature.

Russia

Proso is extensively grown in Central Asia and Soviet Russia. It occurs in Southern Siberia and generally in the southern half of the country from Turkestan to Mongolia. The nomadic peoples, the Mongols and Khirghiz cultivate and consume this grain largely cooked in the form of "kasha". It is frequently grown in dry climates with supplementary irrigation.

Western Asia

Millets have been cultivated for many centuries in this region. In Iran, proso, foxtail and pearl millet are grown in the northeastern, southern and western parts. Pearl millet is cultivated to some extent in southwestern Arabia.

Africa

Millets (mostly pearl and to a lesser extent finger) are widely cultivated in Africa, but most of it is produced under primitive conditions. The most important regions for pearl millets are the peripheries of the Sahara — particularly the southern parts. This millet is also produced in some of the desert oases where some excellent land is watered by springs. The grain is eaten as food, and the stalks provide fuel and building material. Finger millet is grown in many sections of East Africa from Ethiopia and Somaliland to Rhodesia where it is used for food and making beer. Pearl millet is more susceptible to birds and thus has limitations in wooded areas or places where these pests occur.

Pearl millet thrives in areas which formerly constituted French Equatorial Africa particularly in the dry, rocky soil around Lake Chad. The alternating monsoon and dry periods of East Africa favor millet growing. The drier regions of the Sudan grow considerable pearl millet, while the more humid regions may favor finger millet. The highlands of Ethiopia are extensively planted to the grain lovegrass, *Eragrostis teff.* Fonio *(Digitaria* spp.) is grown almost exclusively on the higher, more humid plateaus of several West African countries primarily in Guinea, Mali and Togo.

Eastern Europe

Very little millet has been grown in Western Europe in recent times, but proso and, to a lesser extent, pearl millet are still grown in European Russia, Rumania, Poland and Yugoslavia mainly for porridge or flat bread (proso). Lesser amounts are grown in France, Germany, Bulgaria, Austria and Hungary where it is used chiefly for feed for animals and fowls, making beerormaking brooms.

In Rumania most of the millet plantings are of cattail in the Danube plains. The grain is used principally for feed but in some localities for bread making.The Bulgarians make a favorite beer from their millet. Most of the proso millet in Germany is grown in the south and eastern parts, but is relatively insignificant in quantity. Substantial quantities of pearl millet were grown in France until the end of the nineteenth century when production averaged 575,000 short tons, but now little is grown. Likewise, Spain used to grow small quantities of this crop.

United States

Millets are a minor crop and grown chiefly for hay, although there has been a recent **trend to study further** potential. About 30,000,000 lbs. of grain is **consumed** annually as feed for poultry, swine, and **birds, and for** seed. Much of the production for hay is of foxtail millet, grown in Texas, Kansas, Oklahoma, Nebraska, Missouri, Colorado and Tennessee. Hungarian foxtail is grown in Illinois and Indiana. Barnyard or Japanese millet produced for hay and grain is found in Pennsylvania, New York and Iowa. Proso is grown in North Dakota, South Dakota, Colorado, and Nebraska and is used (as grain) for cattle and chicken feed.

WORLD PRODUCTION OF MILLETS

Statistics on millet production for many countries are often incomplete. Frequently, millet and sorghum are combined or included under feed grains. However, India and Pakistan have provided separate figures for sorghum, pearl millet, finger millet and a combined value for the other four minor m i tlets.

The average annual world production of millets was estimated at about 44 million tons of grain as an average for the five year period 1967 to 1971. Approximately 85 percent of this production was utilized for human food; six percent was used for seed and waste; and about nine percent was fed to livestock. China and India-Pakistan produce more than half of the world's crop; and these countries together with Manchuria, the Soviet Union and French West Africa produce almost nine-tenths of the total. Although the production of millets has surely declined proportionate to that of other cereals over the past 1000 years, particularly in developed regions (Europe), the available statistics and other evidence suggest total production to have increased considerably even during the last thirty years.

The FAO crop production estimates for 1971, Foreign Agriculture (USDA) reports ERS 152 and 153 and other sources have been used to estimate production and study recent trends (Appendix 4). Owing to the infrequency of millets entering trade channels and the tendency of growing these crops in remote areas, it is suggested that the estimates as given here may be conservative by a factor of 20-25 percent. In particular the statistics for Mainland China and Manchuria at 20.76 million metric tons on 29.2 million hectares may be low.

The minimum production of millets for the five year average 1967-71 is estimated at 43.99 million metric tons on 68.8 million hectares (Table 1). This comprises 10.6 percent of the world's cultivated lands devoted to cereals but only about four percent of the grain production. Nevertheless, this quantity of cereal grains is sufficient to feed annually 400 million people utilizing millets as the principal staple of their diet in areas such as India where cereals constitute 80-90% of the total caloric intake.

Asia, even without Russia, is the most important millets growing region of the world --India and China together produced 68% of the total .millets grain crop in 1967-71.The African continent was second with 8.35 million metric tons or one-fifth of the total for this period. Area and production of millets in the world are estimated to have increased by 11 million hectares and 14 million metric tons or about 20 and 47 percent, respectively, from 1962-66 to 1967-71. Greatest increases in production during this period occurred in China and India. The area sown to millets actually declined in Africa and Russia but without much loss in production.

An attempt was made to ascertain the relative importance of the different millet species in the total crop. Only two countries— India and Pakistan— have identified the specific crop in the category "millets" or "feed grains". Therefore, most estimates of relative production were based on "educated guesses" from experience, study of the climate and limited information in the literature. For most African countries it was necessary to do this in two steps: first, to estimate the production of millets when statistics included sorghum; and secondly, to determine the relative proportion of different millets. This projection based on means for the five cropping seasons 1962-66 is given in Appendix 5.

TABLE 1. ESTIMATED WORLD PRODUCTION OF ALL MILLETS FOR THE FIVE YEAR PERIODS 1962-66 AND 1967-71 BY REGIONS (FAO Crop Production Year Book, 1972, vol: 26).

REGION	Area: Millions of Hectares		Production: Millions of Tons	
	1962-66	1967-71	1962-66	1967-71
1. Americas	0.42	0.41	0.37	0.46
2. Africa	17.21	13.73	9.88	8.35
3. Europe (Except USSR)	0.05	0.04	0.06	0.04
4. Russia	3.66	3.18	2.68	3.06
5. Asia (Except USSR)				
a) India	18.58	19.95	7.67	8.90
b) China (Calculated)	15.27	29.20	8.09	20.76
c) Remaining Asia	1.85	1.44	1.11	1.49
Total Asia	35.70	50.59	16.86	31.25
6. Oceania (Australia)	0.03	0.03	0.03	0.03
Grand Total	57.07	68.78	29.88	43.99

Considering production of these crops for the entire world, it is estimated that pearl millet occupies 46 percent of the area and about 40 percent of total millets production. Foxtail millets, more than 85 percent of which are grown in China and Manchuria, may also comprise about a fourth (24.2%) of all millets. Proso *{Panicum miliaceum)* with an estimated 14 percent of the area and 15 percent of the production (produced mainly in Russia and China) ranks third; and finger millet with eight and eleven percent of the total area and production, respectively, is fourth in importance. Table 2 presents a regional breakdown of the different millet species expressed in percent as calculated from previous estimates. Fonio *(Digitaria* spp.) and teff *(Eragrostis teff)* were not included separately above since these two crops are believed highly localized in use. Teff is almost exclusively confined to Ethiopia where about 1.6 million metric tons of grain were produced in 1966. Fonio is grown mainly in West Africa where only about 120 thousand metric tons are produced annually on an estimated 250 thousand hectares principally on small plateaus in savannah lands prossessing slightly heavier soils and somewhat more favorable moisture conditions than the surrounding lower elevations. The principal fonio producing countries during 1963-65 were Guinea (70.000T), Mali (20.000T), Togo (11.000T), Upper Volta (7.000T), Ivory Coast (7.000T), Senegal (4.000T), and Dahomey (2.000T). Yields ranged from 2.5 to 5.4 averaging 4.3 Q/Ha.

Asia and Africa

Africa and Asia (including all of Russia) produce about 98% of the world's millet crop. The developing nations of these two continents (excluding Russia, China and Manchuria) contribute about half of the millets grain production. Pearl and finger millets are mainly grown in these two regions and together comprise 82.6 percent of the total millet grain production for Southern Asia (India, Pakistan, Burma, Nepal, and Sri Lanka) and Africa. Of the two species finger millet contributes a fourth (25.5%) of the millet production in Southern Asia, but only ten percent in Africa.

The nine most important millet producing countries are (1) Mainland China including Manchuria, (2) India, (3) Nigeria, (4) Russia, (5) Ethiopia, (6) Niger, (7) Chad,

TABLE 2. PRINCIPAL PRODUCING REGIONS OF DIFFERENT MILLET SPECIES

SPECIES	REGION	PERCENT OF	
		AREA	PRODUCTION
1. *Pennisetum Typhoides*	Southern Asia (India)	46.6	38.8
	West/North Africa	37.0	44.4
	Central Africa	6.2	8.3
	East Africa	7.5	5.2
	TOTAL	97.3	96.7
2. *Setaria italica*	Eastern Asia (China)	85.8	88.9
	Southern Asia	11.3	7.3
	TOTAL	97.1	96.2
3. *Panicum millaceum*	U.S.S.R.	42.1	52.9
	Eastern Asia	46.0	35.1
	TOTAL	88.1	88.0
4. *Eleusine coracana*	Southern Asia	63.5	61.6
	East Africa	23.7	24.8
	TOTAL	87.2	86.4
5. *Eragrostis teff*	Ethiopia	100.0	100.0
6. *Digitaria Spp.*	West/North Africa	100.0	100.0
7. *Paspalum scrobiculatum*	Southern Asia	95 0+	95 0+
8. Unspecified	Southern Asia	84.5	78.5
	Eastern Asia	15.5	21.5
TOTAL		100.0	100.0

(8) Mali, and (9) Tanzania. Together these countries produce 42.34 million metric tons of grain on 63.08 million hectares annually or 23% of the total production and 93% of the area devoted to millets in the world. Secondary producers are all in Asia and Africa and include Pakistan, North Korea, Uganda, Upper Volta, Senegal, and Sudan with annual production of 253 thousand metric tons on 378 thousand hectares for a total of 5.6 and 5.5 percent, respectively, of the world production and area.

A single species tended to predominate in each of the principal millet producing regions of the world as shown in Appendix 5. This is also true for individual countries as shown by the crop estimate given below:

Country	Predominant Species	Estimated % of total millets
1. M. China-Manchuria	Setaria	75
2. India	Pennisetum	56
3. Nigeria	Pennisetum	98+
4. Russia	*Panicum miliaceum*	91
5. Ethiopia	*Eragrostis teff*	83
6. Niger	Pennisetum	98+
7. Chad	Pennisetum	98+
8. Mali	Pennisetum	97
9. Tanzania	Pennisetum	76
10. Uganda	Eleusine	98

The principal millet in Pakistan, Upper Volta, Senegal and Sudan is pennisetum; while in North Korea it is probably setaria. In the case of India, ragi *(Eleusine coracana)* is the second important species comprising 27 per cent of the total millets production. In Eastern Asia proso *(P. miliaceum)* is second in importance to setaria millet; while in the U.S.S.R. proso is first and setaria is of minor secondary importance:

Production Trends

The general trend in production of all cereals was upward over the twenty year period between 1948-52 and 1967-71. World production increased by 19.8% to 1,114 million metric tons of grain. Individual crops recorded increases of 76 to 129 percent over this same period as shown below:

Crop	World Production 1967-71 (Million M.T.)	Increase over 1948-52 (Percent)
Wheat	323.5	89.0
Rice	294.7	76.0
Maize	270.8	93.6
Barley	135.7	128.7
Millet-Sorghum	89.5	88.9

If only the estimated production of millets is considered, the increase for 1962-66 over 1948-52 would be only about 29.5 percent; although the estimate given by FAO (1967) from production definitely identified as millet (17.2 million metric tons for 1962-66) is somewhat higher or 38.1 percent. The 1 5year increase in the portion identified as sorghum (35.4 million metric tons in 1962-65) is very high at 121.2 percent. However, a large proportion of this increase is attributable to the U.S.A. where production of sorghum grain went from 3.9 to 15.1 million metric tons in 1948-52 and 1962-66, respectively. This increase in sorghum is attributed to the emphasis on feed grains and more efficient production technology coupled with the introduction of cytoplasmic male sterile hybrids in the mid-1950's.

Several crops have contributed to the increasing food requirements of the developing regions where millets are important. An analysis of production trends of the principal cereals in Africa and Asia was made to determine which species contributed most to increased food production during the period between 1948-52 and 1962-66 (See

Table 3). The greatest increase in cereal production occurred in the Far East and by far the highest contributor to this increase was rice, making up nearly three-fourths (73.0%) of the total. In the Near East wheat made up more than half (53.9%) the increase, although barley (not shown) contributed about two million tons of the difference. In Africa, however, maize and millet-sorghums contributed almost equally (42.7 and 42.3%, respectively) to the increased cereal production.

Other food crops contributing to increased consumption were the starchy root crops (potatoes, sweet potatoes, yams and others), pulses and oilseeds. Potatoes added more than one-and-a-half million metric tons to the increased food supply in the Near East, nearly five million tons in the Far East and about one-half million tons in Africa. Other starchy root crops contributed about four million tons in the Far East; but more than six million tons in Africa, where a total of 24.7 million metric tons of root crops including potatoes were produced in 1966 and comprised 36.9% of the total production of cereals and root crops. Oilseeds were of greater significance than the pulses in contributing to the increased food supply in these three regions by adding 1.6, 3.7 and 2.8 million metric tons in the Near East, Far East, and Africa, respectively (Table 3).

The contribution of millets to increased cereal production during the fifteen year period between 1948-52 and 1962-66 is comparatively negligible for the important cereal producing regions of the world except Africa. This suggests that greater emphasis was given to increasing the productive capacity of existing arable lands and of the preferred and more highly improved cereals in Asia, Europe and the Americas; while in Africa much of the increase in production probably resulted from bringing more areas — particularly the more marginal ones -- under cultivation. It also points up the fact that these so-far neglected crops should be relatively easy to improve at the outset and that such improvement could contribute substantially to future food requirements by virtue of their higher productivity under

TABLE 3. INCREASES IN CEREAL PRODUCTION IN ASIA AND AFRICA BETWEEN 1948-52 AND 1967-71 (in millions of metric tons).

CROP	NEAR EAST		FAR EAST		AFRICA		TOTAL ASIA & AFRICA	
	Production	Percent	Production	Percent	Production	Percent	Production	Percent
Maize	4.17	61.9	14.25	115.0	10.93	38.8	29.35	215.7
Wheat	57.11	419.4	25.00	117.0	4.91	42.5	87.02	578.9
Rice	4.54	119.3	142.42	43.8	4.67	78.7	151.63	241.8
Millet-sorghum	4.08	78.0	19.41	45.4	15.22	33.3	38.71	156.7
All Cereals	69.90		201.08		35.73		306.71	

stress or marginal condition; and the fact that they occupy 8.3 percent of the total area devoted to cereals but contribute only 2.75% of the grain production.

UTILIZATION OF MILLETS

Millets have been utilized for human food from prehistoric times. Some students believe the millets were the first cultivated crops. They are said to have been used in China, India and Egypt before there were written records. Proso or bread millet was grown by the Swiss stone age dwellers and has been extensively cultivated throughout Crimea, Turkestan, Mongolia, Manchuria, Tibet and Siberia as a bread grain up to recent times. This crop was also utilized for food in Europe during medieval times but has been gradually superseded by wheat, rye, rice, maize and potatoes. The switch to other cereals is attributed to the recent demand for yeast-fermented bread and higher yields obtainable from the more improved small grains.

Ragi or finger millet was cultivated from the earliest times for food and beverage in India and Central Africa. Pearl millet has also been used for thousands of years in Africa and the Near East but is reckoned to have been a relatively recent introduction into Southern Asia. It is believed that invaders from Western Asia introduced Pennisetum millet into India during the past four to six centuries. However, the expanded use of this cereal may have been relatively recent and associated with the intensified cultivation of marginal lands particularly in the hotter, semi-arid areas. Foxtail millet is one of the principal food crops of China and is probably indigenous to that region. It is also highly regarded in India, being used in puddings and other cereal delicacies as well as cooked like rice or baked as bread.

Information on millet food preparations is limited. However, descriptions of foods prepared from millets were obtained during the systematic collection of millets and maize in India in 1959-62 (Rachie 1964). Dishes prepared out of proso millet at South Dakota State College were described by Hansen in 1915. Other work related to this subject has been published more recently by the Central Food Technological Research Institute at Mysore and the Shri Avinashilingam Home Science College at Coimbatore in India. These results and other experiences indicate that millets can be used for preparing a large number of highly palatable and nutritious foods.

Comparison of Nutritive Values - Grain

Investigations on nutritive values of millets are somewhat limited. The most comprehensive sources of information on this subject are "The Nutritive Value of Indian Foods and The Planning of Satisfactory Diets" by W. R. Aykroyd, C. Gopalan and S. C. Balasubramanian of the Indian Council of Medical Research Nutrition Research Laboratories at Hyderabad (Sixth Edition 1963); and more recently in "Le Sorgho et les Mils en Alimentation Humaine et Animale" by J.Adrian and R.Jacquot (CNRS-Bellevue, France, 1964). The former related principally to unidentified market varieties produced under unspecified conditions; but the latter also includes some analysis on varieties and species within the genus. However, it does provide some interesting information on proximate principles, energy, minerals, vitamins and composition of protein in the different species. Portions of the Aykroyd *et al* and Adrian-Jacquot tables pertaining to proximate principles, minerals, vitamins, lipids, and protein quality are reproduced directly in Appendix 6 - 15. Several other investigators have concentrated on various aspects of chemical composition and nutritive vatues of grain and fodder of individual millet species frequently identified as to genotype and sometimes describing the conditions under which grown. These are briefly discussed under the respective section dealing with that species.

Proximate Principles. Pearl millet possesses the highest number of calories per hundred grams of edible portion and pearl, foxtail and proso are equal to or higher than wheat in protein content. Pearl, foxtail and little millets are also high in fat content and Japanese millet is particularly high in mineral content. Whole millet grain as frequently used is generally higher in fiber content than milled rice or whole wheat. However, the exceptionally high fiber content of foxtail, little, Japanese and Kodo millet given in Appendix 6 and 7 are questioned as applying to unhusked samples considering the South Dakota results on Hansen's White Siberian proso below:

Constituent	Unhusked Sample	Dehusked Sample
Ash	3.51	-
Crude Protein	13.12	16.96
Ether Extract	2.10	3.86
Fiber	8.30	0.95
N. F. Extract	63.07	-

Minerals. Ragi (finger millet) is particularly high in calcium '(300-344 mg or 11.7-14.6% of total ash: eight times more than wheat), magnesium (191 mg), phosphorus (245-283 mg or 8.2-12.6% of ash: 74% phytin), iron (11-17.4 mg) and potassium (408 mg) per 100 g of edible portion. Pearl has good amounts of magnesium (125 mg), phosphorus (269-290 mg or 11.2-22.5% of total ash: 52% phytin) and iron (14.3-42.0 mg: 4.4% ionizable). Italian millet is relatively high in magnesium (120 mg), phosphorus (290 mg: 66% phytin), iron (12.9 mg) and potassium (250 mg). Kodo millet is particularly high in iron (31.1 mg) and magnesium(112mg).Proso is relatively high in iron(11.5mg)

'Quantity given is per 100 g of edible portion.

and phosphorus (206 mg: 40% phytin). Japanese and little millet are relatively high in phosphorus with 280 and 220 mg per 100 g edible portion, respectively (See Appendix 8 and 9).

Vitamins.Pearl millet (0.33mg), Italian millet(0.59 mg), ragi (0.42 mg), little millet (0.30 mg) and Japanese millet (0.33 mg) are high in thiamine; pearl (0.16 mg) and proso (0.18 mg) are medium in riboflavin; pearl (3.2 mg), proso (2.3 mg) and little millet (3.2 mg) have fair levels of nicotinic acid; and proso (748 mg) is exceptionally high in choline. Pearl is also relatively high in Vitamin A possessing 220 International Units per 100 g of edible portion (yellow maize has 1502 I.U.'s) (See Appendix 10).

Lipids. The composition of lipids in kernels of maize, sorghum, Italian millet and proso have been compared by Adrian and Jacquot, 1964 (Appendix 11). Generally the profile and characteristics of grain lipids are quite similar for these four species. Perhaps the most obvious differences among the spec:es is in the fatty acids. Setaria italica is high in the saturated fatty acids (palmitic = 11 p/100; stearic = 14.7p/100); and in the unsaturated linolenic acid (6.4p/100). Proso is similarly high in stearic (12.0 parts) and very high in linolenic (5.5-7.8 parts) acids compared with maize and sorghum. The acid index and hydroxyl index are relatively high in both Setaria and Panicum millets suggesting higher proportions of short-chain fatty acids compared with maize and sorghum.

Protein. Protein quality in millets is generally as good or better than other cereals.[1] Moderate levels of lysine are present in pearl (2.6-3.8 g per 100 g protein), proso (1.85-4.16 g) and kodo (2.1-3.20 g); pearl (1.44-2.35 g), ragi (1.15-1.55 g) and setaria (0.80-2.0 g) are high in methionine; and pearl, ragi, Italian millet, proso, little millet and kodo have 'maximum' levels of threonine ranging

'Amino acids are expressed in grams per 100 g of protein (nitrogen x 16).

from 3.36 to more than 4.0 grams per 100 grams protein. Wheat and rice (parboiled and polished) by comparison have 2.24 and 3.36% of their protein respectively in the form of lysine; 1.12 and 0.96% in tryptophan; 1.92 and 1.28% in methionine; and 2.56 and 3.36% in threonine. Leucine/isoleucine ratios are 2:1 or less for wheat, rice and the millets except Italian and proso millet having ratios of 2.49:1 and 2.15:1 respectively (See Appendix 12-13).

The values for crude protein and amino acid constituents do not accurately reflect the effects of genotype, management and environment on nutritive qualities. Three years of testing hybrid pearl millets by the Cereal Technologist at the Indian Agricultural Research Institute, New Delhi indicate crude protein levels ranging from 12 to 18 percent, with hybrids on CMS Tift 18-A running somewhat higher than those utilizing Tift 23-A as the seed parent (ICAR 1964-65, 1965-66, 1966-67, 1967-68). Two independent analyses of pearl millet hybrids and inbred lines resulted in the discovery of one white-pearly inbred, Bichpuri, containing up to 23 percent crude protein. In subsequent investigations Bichpuri and other important stocks were tested for both protein and lysine contents. The lowest protein line, BIL 3B, also had the highest lysine content of 3.05 g per 100 g protein; however, three high protein stocks -- TF 23A x D 356 (17.8% protein), D 118 (21 .7% P) and Bichpuri (23.0% P) -- had lysine contents of 2.55 g, 1.97 g, and 1.98 g of lysine per 100 g of protein, respectively (IARI.1968). Similarly, white-pearly grain ragi strains are found to contain about 10-14% protein or 50 to 100% more than ordinary red or brown seeded types (Kadkol and Swaminathan1956).

Feeding Trials. Millet grain is used directly for human food in Africa and Asia but primarily for feeding poultry and livestock in Europe and the Americas. Unfortunately, there is relatively limited work on the feeding values of different millet grains. Proso grain was compared with maize as a feed for laying hens in North Dakota by Goodearl

(1943). Rating a maize diet as 100 he found the efficiency of proso grain to be 107% and 96% for white Leghorns and Rhode Island Reds, respectively. It was concluded that proso was equal to maize as feed for these chickens. Other experiments on swine feeding have shown proso equivalent to barley in producing live weight gains (Wilson, 1948).

Rat feeding trials have been conducted on different millet grains. Among the more interesting of these were experiments comparing foxtail millet and maize conducted by Mangay *etal.* (1957). They found that niacin added to a 40% maize or millet diet increased the mean growth rate of the maize diet from 40 to 108 gm for the 29 day period, but had no effect on the millet diet which alone produced gains of 109 gm for the same period. Although the niacin content was low (0 .49 mg/100 g EP) in the millet diet, the tryptophan content was higher — 192 mg per 100 gm of millet diet compared with 133 mg per 100 gm of maize diet. The higher level of tryptophan in the millet was believed responsible for these results. Evidence was also presented to show that lysine supplementation of a foxtail millet diet enhanced the 21-day weight gain in rats by four-and-a-half times. The conclusion drawn is that foxtail millet has a satisfactory tryptophan content.

Kodo millet *(Paspalum scrobiculatum)* was compared with whole wheat in rat feeding trials by Kadkol ef *al.* (1954). Wheat was found significantly superior to husked kodo grain by an advantage of 9.01 gm to 5.20 gm average weekly gain in live weight.

A human feeding experiment using eight 11 and 12 year-old boys on different proportions of pearl millet and rice flour was reported by Kurien *et a l.* (1967). The mean daily intake of nitrogen, and minerals increased from 6.92 to 8.67 gm of N, 352 to 479 mg of Ca, and 726 to 1346 mg of P in diets ranging from all rice, to one-fourth millet, one-half millet and all pearl millet. However, the balance of nitrogen and calcium declined although remaining positive in the higher millet diets. The situation was different with phosphorus where the balance increased as the intake of pearl millet increased. The faecal bulk also increased with higher levels of millet in the diet indicating a higher proportion of cellulose and hemicellulose in Pennisetum grain.

Loss in Milling. Often considerable loss of nutrients occur in milling and other processes preparatory to cooking. Indigenous methods sometimes involve alternately soaking and drying accompanied by loss of water-soluble constituents. Investigations on native processing of maize, sorghum, Pennisetum and Eleusine in Rhodesia indicate that up to 45% in dry matter, 44% in protein, 84% in lipids, 87% in minerals, and over 90% of thiamine and riboflavin may be lost in these precooking processes. Maize appears to lose the most and the two millet species, Pennisetum and Eleusine, the least in the local Rhodesian processing operation. Possibly maize is more thoroughly soaked and bleached during this precooking milling process (See Appendix 14).

Composition of Forage

The composition of fresh and dry forage varies considerably depending on stage of harvest and conditions under which grown and preserved. The major influence on quality appears to be stage of growth at cutting or grazing. Between seedling stage and grain maturity different species decrease in dry matter content, protein, lipids, and ash; and increase in crude fiber, nitrogen-free extract, and dry matter content. Among the different species in presumably comparable stages of maturity, Japanese millet hay was outstandingly high in protein and ash -- higher than other hays in lipids, calcium, phosphorus and potassium and substantially lower in crude cellulose. As pasture and ensilage *Pennisetum typhoides* was high in protein, lipids and calcium; and low in crude fiber. Young napier grass was also high in protein and ash -- particularly in potassium. Foxtail millet *(Setaria italica)* analyzed as "fresh material" was relatively high in protein, lipids, nitrogen-free extract, and potassium (See Appendix 15).

Industrial Uses

The nutritive values of millets for human or animal feed are, at least, partially established. Their potential for special and industrial uses requires further study and consideration. Millet grains are extensively used for making alcoholic beverages but only ragi is known to have malting qualities similar to barley and sorghum. Vegetable oils might possibly be a by-product of starch extraction from pearl millet (5.0-7.0% fat), foxtail millet {4.3% fat) and little millet (4.7% fat). Although not actually tested, sugary endosperm occurs as "dimpled" seeds in some pearl millet lines as in sweet corn and sugary endosperm sorghums. The discovery of waxy or high amylose endosperm in bajra or other millets can only be postulated from their occurrence in maize and sorghum, but carotenoid yellow endosperm is an established fact based on findings in Nigeria by Curtis and Burton (1966). The possible discovery of the right kind of glutenous starch or other means to readily prepare rising bread from millets might well change the entire perspective of cereal consumption in the world. Admittedly this is a "far-out possibility" but one with high stakes.

OUTLOOK FOR MILLETS

Collectively the millets have a wide range of adaptation and use. There are types to fit almost every situation and need — particularly if conditions are somewhat less than ideal for other crops. Species and varieties are available for high temperatures and low humidities, or low temperatures and high humidities; heavy, light, stony or relatively infertile soils; varying elevations; occasional flooding or limited moisture conditions; and short or long seasons. Desirable characteristics like high nutritive values, relatively few insects and disease pests, economy of water use, tolerance of alkalinity, drouth resistance, production under temperature extremes, good fcdder qualities and special grain characters are important assets in expanding the uses of these crops. Moreover, few crops respond as markedly to modest increments of fertilizers as pearl millet and ragi do. The identification of the most highly responsive lines coupled with the "re-engineering" of plant type and experimentation on management are expected to make these among the highest "unit area/time productive" cereals. The new profuse and uniformly-tillering, large-earhead dwarf inbred lines of pearl millet responsive to high fertility and population levels under development in the accelerated millet breeding program in India may portend the future in this direction.

Conservative estimates place world millet production at only thirty million tons of grain annually or approximately 2.9 percent of the total cereal production. Inasmuch as most of this production occurs in developing regions where cereals form the bulk of the diet, this quantity of millets grains could provide major sustenance for up to 200 million people. In addition, the residue or straw provides undetermined quantities of forage for cattle, fuel for cooking, thatching and other purposes. Although there appears to be a modest increase in the recent production of millets, further expansion will be severely limited unless improvement efforts are substantially increased.

Millet grain yields are frequently unusually low in most of the world. This is attributable to the marginal conditions under which these crops are frequently grown, unavailability of improved strains or lack of information about good management practices. Nevertheless, it follows that rapid increases in production will accrue as advances towards improvement are achieved and gains in knowledge made. The present uses of millets will probably expand for other reasons. These are the encouragement of multiple-cropping accompanied by the application of chemical fertilizers and greater realization of economical water use. In multiple cropping schemes there is frequent need for at least one short-term, economical water-using crop in the rotation. In terms of water use alone, the question arises whether it is desirable to grow one long season or two or more successive short-duration crops. Another aspect is whether it is better to grow five to ten hectares of millets or one of rice. Increasingly, such questions require answering in the quest of meeting the increasing needs for human sustenance and better quality nutrition, in addition to economic considerations.

Increases in food production in the future will result largely through higher yields and bringing more land under cultivation. Increased irrigation may not be an important factor. Addison (1961) states that (1) less than ten percent of the world food production comes from irrigated or artificially drained lands; (2) less than 5% of the food supply depends on "engineered scale" control of water; and (3) of the estimated increase in world food supply over the next half century, not more than a tenth can be expected as a result of new, large-scale engineering works.

The total arable lands of the world constitute only about ten percent of the earth's total land mass of 13,531 million hectares. Major crops are grown on about 900 million hectares and approximately 495 million hectares are used for minor crops, fallow and temporary pasture. An additional 2,569 million hectares are used as permanent meadows and pastures.

Largest areas of potentially cultivable lands occur in the tropics of the Americas, Africa and Southeastern Asia. Salter (1947) estimated that 20% of the unexploited red soils of Africa and South America might be cultivated adding 360 million hectares; plus 40 million hectares in Sumatra, Borneo, New Guinea, Madagascar and other tropics. Some of the arid desert and semi-arid highlands may also be irrigable to bring some additional "hundreds of millions of hectares" under cultivation. Up to 10% of the podzolic soil zones of northern U.S.S.R. and Canada may be cultivable adding 300 million hectares. Kellogg (1967) believes 1,780 million hectares of new land are potentially arable. These estimates would seem to imply that an "outside limit" of up to 1.8 billion hectares may be added to the total cultivable land resources of the world.

The bulk of the potentially cultivable lands are expected to be marginal for one or more major growing conditions. This will dictate increasing livestock production in these areas, but the portions allocated to food crops will frequently better suit the cultivation of millets rather than the less hardy cereals. Assuming that millet improvement can be accelerated and continue to make satisfactory progress, production might possibly be expanded by increased yields by up to fifty percent on the present acreage through double-cropping and replacing less profitable crops and by utilizing as much as five percent of potentially cultivable new lands. Thus, a gradual increase of millets production over the next three to five decades from the present 57 million hectares up to 150 million hectares producing up to 120 million metric tons of grain annually is theoretically possible.

BIBLIOGRAPHY

I. Text references

1. Addison, H. "Land, Water and Food". (L. p. 268). Chapman and Hall Ltd., London, 1961.
2. Adrian, J. and R. Jacquot. "Le Sorgho et les Mils en Alimentation Humaine et Animale." Centre Recherches sur la Nutrition Du C.N.R.S. Bellevue (Seine-Et-Olse). Vigot Freres, Editeurs, Paris, 1964. p. 189.
3. Anderson, Elna. "Millet Provides Food for Millions." Foreign Agriculture. 12(11): 235-239. 1948.
4. Aykroyd, W.R., C. Gopalan and S.C. Balasubramanian. "The Nutritive Value of Indian Foods and the Planning of Satisfactory Diets." Indian Council of Medical Research, New Delhi. Special Report Series, No. 42, pp. 49-50,83-84, 114-115 and 137. 1963.
5. BSCP (Biological Sciences Communications Project of George Washington University). "The Millets. A Biblography of the World Literature covering the Years 1930-1963". The Scarecrow Press, Inc., 1967.
6. Curtis, D.L., G.W. Burton and O.J. Webster. "Carotenoids in Pearl Millet." Crop Sci. 6:300-301. 1966.
7. Food and Agriculture Organization (UN). "Yearbook of Production-1966". FAO (UN), Rome. Vol. 21:63-71. 1968.
8. Goodearl, C.P. "Comparison of Proso Millet and Yellow Corn for Feeding Laying Hens." Bull. N. Dak. agr. Exp. Sta., 329. p.23. Dec. 1943.
9. Hansen, N.E. "Proso and kaoliang in table foods." South Dakota Agric. Exp. Sta. Bui. 158. 1915.

10. Indian Agricultural Research Institute. Annual Progress Report of the Scheme for Studies on Protein Quality of Sorghum, Millet, Wheat and other Cereal Grains for the Period 1967-68, New Delhi, India. 1968.

11. Institut Recherches Agronomiques Tropicale. Informations Economiques: Les Cereales en Afrique. Agron. Trop. 23:878-910. 1968.

12. Hector, J.M. "Introduction to the Botany of Field Crops. Volume I - Cereals Ch. VIII, pp. 307-319. Central News Agency Ltd., Johannesburg, South Africa, 1936.

13. Indian Council of Agricultural Research. "Progress Report of the Coordinated Millets Improvement Program 1964-65, 1965-66, 1966-67 and 1967-68." I.C.A.R., New Delhi, 1965-68.

14. Kadkol, S.B. and M. Swaminathan. ''Chemical Composition of Different Varieties of Ragi *(Eleusine coracana)'/* The Bull. C.F.T.R.I. (Mysore, India), Vol. IV (1): 12-13. 1955.

15. Kadkol, S.B., V. Srinivasamurthy and M. Swaminathan. "Nutritive Value of the Seed of *Paspalum scrobiculatum."* J. Sci. Ind. Res. 13B(10): 744-745. 1954.

16. Kellogg, C.E. "Half of World's Arable Soils are Being Farmed." The Sacramento Bee (Newspaper), June 16, 1967.p.CL8. Sacramento, Calif. 1967.

17. Kurien, P.P., M. Swaminathan and V. Subrahmanyan. The effect of Partial or Complete Replacement of Rice in Poor Vegetarian Diets by Pearl Millet *(Pennisetum typhoides)."* Brit. J. Nutr. 15:345. 1967.

18. Leonard, W.H. and J.H. Martin. "Cereal Crops." pp. 740-769. 824p. The MacMillan Co., New York. 1963.

19. Mangay, A.S., W.N. Pearson and W.J. Darby. "Millet *(Setaria italica).* Its Amino Acid and Niacin Content and Supplementary Nutritive Value for Corn (Maize)." J. of Nutrition 62:377. 1957.

20. Mansfield, R. "Zur Systematik and Nomenklatur der Hirsen (Systematics and Nomenclature of the Millets)." Zuchter1952. 22:304-315.

21. Matz, S.A. "Chemistry and Technology of Cereals." p. 178. The AVI Publishing Co., Westport, Conn, pp. 732.1959.

22. Rachie, K.O. "The Systematic Collection of Sorghums, Millets and Maize in India." Report of the Rockefeller Foundation and the Indian Council of Agricultural Research, New Delhi. 1965.

23. Salter, R.M. "World Soil and Fertilizer Resources in Relation to Food Needs." Science Vol. 105:533-538. May 23, 1947.

24. Stebbins, G.L. and B. Crampton. "A Suggested Revision of the Grass Genera of Temperate North America." Recent Advances in Botany, pp. 133-145. The University of Toronto Press, 1961.

25. United States Department of Agriculture -- Economic Research Service. "World Agricultural Production and Trade Statistical Report -- ERS 152 and 153." Washington,D.C. 1966.

26. Wilson, H.K. "Grain Crops." pp. 260-264. 372 p. McGraw-Hill, New York.

II. Sources for Biochemical Analyses (from Adrian and Jacquot)

1. Adolph. Philippine J. Sci., 1926, 30, 287.
2. Adrian, Sayerse C. Composition des mils et des sorghos du Senegal. Monographie 0.R.A.N.A., 1954, Direction Generate de la Sante Publique, Dakar, edit.
3. Anonymous. Queensland Agric. J., 1 958, 579.
4. Balasubrahmanyan, S.C., Ramachandran, M. and Viswanatha, T. De S.S., Indian J. Med. Res., 1952, 40,73 et 219.
5. Balland, C.R. Ac. Sci., 1902, 135, 1079.
6. Baumgarten, W., Mather, A.N. and Stone, L. Cereal Chem.,1946. 23, 135.
7. Bressani, R. and Rios, B.J. Cereal Chem., 1962, 39, 50.
8. Busson, F., Lunven, P., Lanza, M., Aquaron, R., Gayte-Sorbier, A. and Bono, M. Agron. Trop., 1962, 752.
9. Calder, A. Rhodesia Agric. J., 1960, 57 - 116.
10. Carbiener, R., Jaeger, P. and Busson, F. Ann. Nutrit. Alim,, 1960, 14, 165.
11. Chamberlain, U.S. Dept. Agric, Bur. Chem., Bull. No. 120, 1909.
12. Church. Watt's Die Econ. Prod. India, Calcutta 1889, Part I. 130.
13. Eckey, E.W. Vegetable fats and oils, 1 Vol. New York 1954, ReinholdPublis. Edit.
14. F.A.O., Table de composition des aliments, mineraux et vitamines. Rome, March, 1954.

15. Francis, Friedemann, Oklahoma Agric. Exp. Sta. Bull. No.117, 1917.

16. Gayte-Sorbier, A., Saurat, A., Busson, F. and Lunven, P. J. Agric. Trop. Bot, Appli. 1960,7, 383.

17. Hilditch, T.P. The chemical composition of natural fats, 1 Vol., London 1956, Chapman and Hall, Edit.

18. Jansen, G.R., Di Maio, L.R. and Hause, N.L.Agric. Food Chem.1962. 10,62.

19. Kadkol, S.B. and Swaminathan, M. Science and Culture, 1955, 20,340.

20. Kuppuswamy, S., Srinivasan, M. and Subrahmanyan, V. Proteins in foods. Indian Council of Medical Research, New Delhi, 1958.

21. Kurien, P. P., Rao. N. M., Swaminathan, M. and Subrahmanyan, V. Food Sci., 1960, 9, 205.

22. Lanza, M., Regli, P. and Busson, F. Med. Trop., 1962, 22, 471.

23. Lindsey. Massachusetts Agric. Exp. Sta., 1919.

24. Mangay, A.S., Pearson, W.N. and Darby, W. J. J. Nutrit., 1957, 62,377.

25. Morrison, F.B. Feeds and Feeding. 1 Vol., New York, 1950. Morrison Publis. Edit.

26. Narayana, Norris J. Indian Inst. Sci., 1928, 11A, pt 8, 91.

27. Nicholls, L. Tropical Nutrition and Dietetics, 1 Vol., London, 1951, Bailliere Edit.

28. Porteres, R.J. Agric. Trop. Bot. Appli., 1955, 2, 349, 477, 620.

29. Porteres, R. J. Agric. Trop. Bot. Appli., 1959, 6, 680.

30. Ramachandran, M. and Phansalkar, S.V. Indian J. Med. Res., 1956, 44, 501.

31. Randoin, L., Le Gallic, P. and Causeret, J. Table de composition des aliments, 2nd Edit., Lanore Edit.

32. Rao, G.R. and Swaminathan, M. Bull. Central Food Technol., Mysore, 1953, 3, 68.

33. Thebaud, A. and Fournier, P. Rapp. No. 3 Mission Anthrop. Dakar, 1957.

34. Williams, H.H. Cornell Univ. Memoir 337.

35. Woll, Wisconsin Agric. Exp. Sta. 1899.

36. van Wyk, H.P.D., Costhuizen. S.A. and Meyer, E.E. The nutritive value of South African feeds. Dept. Agric. S. Africa. Bull. No. 354, 1955.

APPENDIX 1. A TAXONOMIC SCHEME FOR THE CLASSIFICATION OF SIXTEEN MILLETS AND MINOR CEREALS OF THE FAMILY GRAMINEAE (adapted from Stebbing and Beecher 1961)

Sub Family	Tribe	Genus	Species
Eragrostoideae*	Eragrosdeae	*Eragrostis*	*tef*
	Chlorideae	*Eleusine*	*coracana*
Panicoideae	Paniceae	*Digitaria*	*iburus, axilis*
		Brachiaria	*ramosum*
		Paspalum	*scrobiculatum*
		Panicum	*nilliaceum, miliare*
		Echinocloa	*crusgalli* var. *frumentacea, colonum, decompositum*
		Setaria	*italica*
		Pennisetum	*typhoides*
	Andropogoneae	*Coix*	*lachryma-jobi*

* Pilger Bot .Jahrb .76:334, 1954

APPENDIX 2. GROUPING OF THE CEREALS ON THE BASIS OF CERTAIN BOTANICAL CHARACTERS (after Leonard and Martin, 1963)

1. Cool season, long-day, nitronegative (high soil nitrogen delays maturation) winter or spring habit plants: wheat, oats, barley and rye.

2. Warm-season, short-day, nitropositive (high soil nitrogen hastens maturation), spring habit plants: rice, corn, sorghum and millets.

3. Winter resistance: Rye >Wheat>barley >oats.

4. Secondary growth tendency: Rice > Sorghum > millets >oats >barley >wheat>corn.

5. Seminal roots:

   ONE: Rice, sorghum, pearl millet and proso.

   THREE TO SEVEN: Corn, wheat, oats, barley, rye and foxtail millet.

6. Stems:

   Solid (pithy): corn, sorghum, pearl millet.

   Mostly hollow, except at nodes: other cereals.

7. Small seeds and seedlings compared with mature plant size: sorghum and millets.

APPENDIX 3. TAXONOMIC KEY TO THE CLASSIFICATION OF THE CEREALS (after Hector, 1936)

The different cereal crops may be separated by a key to the genera to which they belong.

1a. Flowers all unisexual, the pistillate crowded on a thick rachis (the cob) the staminate at the top of the plant (the tassel).......... *Zea* (Maize).

1b. At least some of the flowers perfect, nothing resembling cob or tassel present.

2a. Inflorescence a spike, one to a culm.

3a. Only one spikelet present at each joint of the rachis.

4a. Glumes narrow and subulate, one-nerved...... *Secala* (Rye).

4b. Glumes broad and ovate, at least three nerves present.......*Triticum* (Wheat).

3b. Three spikelets present at each rachis joint (the 2 lateral ones sometimes each reduced to a pair of glumes)........*Hordeum* (Barley).

2b. Inflorescence a panicle or of more than one spikelike raceme.

5a. Spikelets of two or more similar florets, the whole over 0.75 inch long (15 mm)............. Avena (oats).

5b. Spikelets of only one floret or of two very unlike florets, the whole much less than 0.75 inch long.

6a. Spikelets definitely compressed laterally, glumes both much shorter than the spikelet ....Oryza (Rice).

6b. Spikelets round or dorsally compressed; second glume (at least) about as long as the spikelet.

7a. Lemma and palea thin and papery in texture much thinner than the two glumes.... Sorghum (Grain sorghum).

7b. Lemma and palea of the perfect flowers hard and shiny, never thin in texture, much thicker than the two glumes.

8a. Spikelets subtended by bristles.

9a. Bristles falling with spikelet at maturity... *Pennisetum*.

9b. Bristles not falling with spikelet...... *Setaria*.

8b. Spikelets not subtended by bristles.

10a. Spikelets with awns at least one mm. long.......*Echinocloa*.

10b. Spikelets awnless or merely awn pointed, less than one mm. long....... *Panicum*.

11a. Inflorescence a diffuse panicle....... *P. miliaceum*.

11b. Inflorescence of several spikelike racemes.

12a. Racemes along an angled axis....... *P. ramosum*.

12b. Racemes digitate with two to six spikes.......*Eleusine*.

APPENDIX 4. PROJECTED AREA AND PRODUCTION OF MILLETS BY COUNTRIES FOR THE FIVE-YEAR PERIODS 1948-52 AND 1967-71

Continent and country	Area 1000 Ha.		Yield (Q./Ha.)		Production 1000 Metric tons	
	1948-52	1967-71	1948-52	1967-71	1948-52	1967-71
Europe:						
Austria	3	1.6	11.0	23.1	3	3.8
Bulgaria	15	1.4	7.5	10.8	11	1.6
Czechoslovakia	6	1.0	11.4	15.2	7	1.4
France	6	1.0	9.0	16.3	5	1.4
Greece	2	1.2	7.2	9.5	1	1.2
Hungary	11	3.6	7.2	9.6	8	3.4
Poland	60	21.4	10.1	12.5	61	26.8
Spain	4	1.6	9.9	23.6	4	3.6
Yugoslavia	18	7.4	6.9	9.4	13	7.2
TOTAL	119	39.8	8.9	12.6	106	50.4
U.S.S.R.	3767	3183.8	4.5	8.94	1705	2853.4
North America + Central America						
Haiti	242	238	7.1	8.6	171	187
TOTAL	242	238	7.1	8.6	171	187
South America						
Argentina	177	175.6	8.3	10.8	146	191.4
TOTAL	177	175.6	8.3	10.8	146	191.4
Africa:						
Angola (U)	--	91.6	--	8.4	--	77.2
Botswana	6	17.0	2.3	3.7	1	5.0
Burundi	40	34.6	5.5	7.4	22	25.8
Cameroon	654	538.0	5.7	7.2	371	385.6
Central Africa Rep.	54	76.8	5.0	5.8	27	44.0
Chad (U)	1030	1015.8	6.4	6.84	655	693.2
Dahomey	115	131.0	4.6	5.3	53	70.0
Ethiopia	3397	3973.0	5.1	6.3	1727	2583.0
Gambia (U)	52	41.6	4.6	10.0	24	41.8
Ghana	175	184.0	5.7	4.9	99	89.4

APPENDIX 4 – continued

Continent and country	Area 1000 Ha.		Yield (Q./Ha.)		Production 1000 Metric Tons	
	1948-52	1967-71	1948-52	1967-71	1948-52	1967-71
Guinea (U)	228	260.0	4.1	5.8	93	151.0
Ivory Coast	79	86.8	4.2	4.7	33	41.6
Kenya (U)	318	--	8.1	--	256	--
Libya (U)	2	2.0	8.6	7.1	2	1.0
Mali (U)	1268	1194.0	5.4	6.8	682	805.0
Mauritania (U)	75	110.0	6.0	8.6	45	88.2
Morocco	29	7.4	5.5	5.9	16	4.2
Mozambique	19	19.0	5.3	5.3	10	10.0
Namibia	33	41.6	4.7	3.1	16	13.0
Niger	1058	2082.0	3.5	4.7	371	966.2
Nigeria	3240	3312.0	5.4	8.06	1760	2677.0
Rhodesia	297	390.0	2.3	6.2	67	243.8
Rwanda	9	2.8	2.3	6.2	67	243.8
Senegal	782	1061.0	3.9	5.2	308	562.0
Sierra Leone	10	8.0	15.7	16.4	15	12.8
Somalia (U)	77	348.0	3.9	1.7	30	58.4
South Africa	19	21.6	5.3	6.6	10	14.4
Sudan	352	654.0	5.2	5.84	181	386.0
Tanzania	93	130.4	7.5	10.28	70	134.6
Togo (U)	175	330.6	5.3	4.4	92	147.8
Uganda	448	541.8	7.4	11.4	330	618.2
Upper Volta	653	763.2	3.4	4.9	221	373.0
Zaire (U)	90	35.4	6.2	8.3	56	30.0
Zambia	240	311.0	7.6	8.6	181	268.0
TOTAL (M)	6562	8296.0	5.0	6.8	3253	5616.0
(U)	--	9878.0	--	6.4	--	6334.6
Asia:						
Burma (U)	199	207.2	3.5	2.6	70	55.2
Sri Lanka	38	23.2	4.8	6.8	18	16.2
India	16605	19954.0	3.7	4.9	6064	9796.0
Iran	15	17.8	10.7	10.6	16	18.8
Iraq	10	3.8	13.2	10.5	13	4.4
Japan	113	9.8	11.2	17.3	127	16.8
Korea	470	--	6.8	--	320	--
Korea Rep.	191	7.9	3.1	7.0	60	54.2
Nepal (U)	51	101.6	10.2	11.1	52	11.3

APPENDIX 4 - continued

Continent and country	Area 1000 Ha.		Yield (Q./Ha.)		Production 1000 Metric Tons	
	1948-52	1967-71	1948-52	1967-71	1948-52	1967-71
Pakistan	918	760.0	3.7	4.6	342	353.4
Saudi Arabia	6	16.0	10.4	9.7	6	16.0
Syrian Arab Rep.	93	31.2	7.0	8.1	65	26.2
Taiwan	7	5.2	7.7	12.9	5	6.6
Turkey	74	38.6	10.6	12.9	78	50.0
Yemen AR (U)	416	372.0	17.4	13.4	724	500.0
TOTAL (M)	18448	8296.4	3.8	6.7	7050	5615.0
(U)	--	9878.0	--	6.4	--	6334.6
China Peoples' Republic (U)	27720	29225.2	5.0	7.0	13855	20778.8
Oceania						
Australia	7	32.0	10.0	9.9	7	28.6
TOTAL	7	32.0	10.0	9.9	7	28.6
WORLD TOTAL	29144	68781.2	4.3	6.4	12418	43992.4

U = Unspecified (Millet + Sorghum)
M = Millet

APPENDIX 5. ESTIMATED PRODUCTION OF DIFFERENT MILLET SPECIES DURING 1962-66 IN IMPORTANT GROWING REGIONS

REGION	ALL MILLETS		PENNISETUMS		SETARIAS		P MILIACEUM		ELEUSINES				PROPORTION % AREA: PRODUCTION
	1000 HA	1000 J	1000 HA	1000 J	1000 HA	1000 J	1000 HA	1000 J	1000 HA	1000 J	1000 HA	1000 J	
1. North & Central America (2)	269	196	233	170	4	3	32	23					0.7
2. South America	150	172			10	12	140	160					0.6
3. Europe (9)	50	58	3	4			47	54					0.2
4 U.S.S.R.	3664	2682			353	232	3311	2450					9.0
5. Western Asia (6)	127	131	35	33	21	21	71	77					0.4
6. Southern Asia (5)	19632	8178	12169	4666	1511	529	626	219	2818	2085	2514[u]	679[u]	27.4
7. Eastern Asia (6)	15938	8553			11485	6440	3617	1628	374	300	462[u]	185[u]	28.6
8. Oceania	27	28			5	5	22	23					0.1
9. West and North Africa (5)	9961	5477	9679	5340					25	19	257[d]	118[d]	18.3
10. Central Africa (7)	1732	1097	1612	1002					120	95			3.7
11 East Africa (8)	5027	3067	1953	628					1049	839	2025[t]	1600[t]	10.3
12. South Africa (4)	491	238	442	194					49	44			0.8
TOTAL	57074	29887	26126	12037	13389	7242	7866	4634	4435	3382	5258	2118	
PERCENT			45.8	40.3	23.4	24.2	13.8	15.5	7.8	11.3	9.2	8.6	

1. North and Central America: Haiti & USA.
2. South America: Argentina.
3. Europe: Poland, Hungary, Yugoslavia, Spain, Bulgaria, Austria, Czechoslovakia, France, Greece.
4. USSR: Both European & Asiatic Russia.
5. Western Asia: Iran, Iraq, Saudi Arabia, Southern Arabian Federation, Syria, Turkey.
6. Southern Asia: India, Pakistan, Burma, Nepal, Sri Lanka.
7. Eastern Asia: Mainland China, Manchuria, N. Korea, S. Korea, Japan and Taiwan.
8. Oceania: Australia.
9. W & N Africa: Nigeria, Niger, Senegal, Mali, Upper Volta, Guinea, Mauritania, I. Coast, Ghana, Togo, Dahomey, Gambia, S. Leone, Libya, & Morocco.
10. Central Africa: Sudan, Chad, Centrafrique, Zaire, Cameroons, Ruanda, Burundi.
11. East Africa: Ethiopia, Kenya, Tanzania, Uganda, Somalia, Mozambique, Zambia & Madagascar.
12. South Africa: S.Rhodesia, S. Africa, S.W. Africa, Botswana.

u = Unspecified minor millets: principally *paspalum, scrobiculatum, Echinoltoa colonum* & *Panicum miliare*.

d = Forio. *Digitaria exilis* & *D. iburua*.

t = Teff; *Eragrostis tef*.

APPENDIX 6. PROXIMATE PRINCIPLES AND ENERGY IN MILLETS AND OTHER SELECTED CEREALS (Aykroyd et al. 1963, pp. 49-50)

Crop	Percent of Edible Portion						
	Moisture	Protein	Fat	Minerals	Fiber	Other CHO's	Calories per 100 g
1 Pearl Millet-dehusked	12.4	11.6	5.0	2.3	1.2	67.5	356
2 Foxtail millet-dehusked	11.2	12.3	4.3	3.3	8.0*	60.9	331
3 Proso millet-dehusked	11.9	12.5	1.1	1.9	2.2	70.4	341
4 Finger millet-as purchased	13.1	7.3	1.3	2.7	3.6	72.0	328
5 Japanese millet-dehusked	11.9	6.2	2.2	4.4	9.8*	65.5	307
6 Kodo millet-dehusked	12.8	8.3	1.4	2.6	9.0*	75.9	307
7 Little millet-dehusked	11.5	7.7	4.7	1.5	7.6*	67.0	340
8 Sorghum-as purchased	11.9	10.4	1.9	1.6	1.6	72.6	349
9 Rice-parboiled, milled	13.3	6.4	0.4	0.7	0.2	79.0	348
10 Wheat-whole	12.8	11.8	1.5	1.5	1.2	71.2	346
11 Maize-dry	14.9	11.1	3.6	1.5	2.7	66.2	342

*These values are questioned as being on dehusked samples considering results obtained at Brookings, S. D. See text.

APPENDIX 7. PROXIMATE PRINCIPLES IN MILLET GRAINS OF DIFFERENT SPECIES AND ORIGINS (Summarized by Adrian and Jacquot, 1964)

	Sample No	Moisture %	Protein %	Fat %	CHO	Fiber	Ash
PENNISETUM							
P. typhoideum, Calder (9)	2	12 4	9.9	4.2	69.1	1.8	2.6
P. typhoideum, Porteres (29)		11.4	12.1	5.8			2.0
P. typhoideum, Church (12)		11.3	10.4	3.3	71.6	1.5	2.0
P. typhoideum, Balland (5)		14.0	16.1	6.25	71.2	3.85	2.1
P. typhoideum, Nicholls (28)		12.0	11.0	3.0	70.0	1.5	2.5
P. typhoideum, Thebaud (33)	2	11.8	9.2	4.65	70.2		1.55
P. nigritarum, Adrian (2)	2	8.3	12.3	5.6	69.0		1.7
P. pycnostachyum, Adrian (2)	4	9.0	10.2	4.75	70.1		1.55
Cultivars Indigenous to Senegal:							
Early (souna), Adrian (2)	3	9.35	9.0	5.2	68.2		1.5
Late (sanio), Adrian (2)	4	8.95	9.9	4.9	68.3		1.6
PANICUM							
P. miliare, Porteres (29a)		11.8	11.4	3.1	59.7		5.0
P. miliaceum, Wolf (35)		11.3	9.45	3.8	61.1	10.7	3.55
P. miliaceum, Chamberlain (11)	38	8.9	12.75	3.25	71.2	8.95	3.8
P. miliaceum, Lindsey (24)	4	12.0	11.1	3.7	62.9	7.7	2.6
ELEUSINE							
E. coracana, Porteres (29a)		12.35	7.6	1.35	74.75		2.35
E. coracana, Nicholls (28)		12.0	8.0	1.3	72.0	3.0	3.0
E. coracana, Adolph (1)		8 5	5.85	5.75	74.2	2.0	3.65
E. coracana, Narayana *et al* (27)		0.0	8.4	1.7	83.8	3.4	2.7
E. coracana, Church (12)		12.5	5.9	0.8	74.5	3.5	2.5
E. coracana, Calder (9)	2	13.5	6.7	1.3	70.8	3.5	4 2
E. coracana, Gayte-Sorbier (16)	1	11.65	6.0	1.2	72.0	6.8	2.25
SETARIA							
S. korean, Anonymous (3)		10.0	11.4	3.0	66.7	6.6	2.3
divers	4	10.0	11.4	4.3	64.4	7.0	2.85
S. italica, Kadkol *et al* (20)		10 8	11.3	5.2	61.6	7.7	3.4
S. italica, Porteres (29a)		11.1	11.3	4.8	60.8		3.45
S. italica, Nicholls (28)		12.0	11.0	4.0	63.0	7.0	3.0
PASPALUM							
P. scrobiculatum, Porteres (29a)		12.3	7.55	3.35	68.6		2.9
P. longiflorum, Porteres (29a)	2	11.6	8.7	2.25	76.0		1.5
P. longiflorum, Porteres (29)	8	12.3	7.3	1.8	74.7	1.6	1.6
P. longiflorum, Thebaud (33)	5	10.4	4.5	3.0	55.0	6.3	1.6
		13.65	8.0	4.6	70.2	9.9	7.5
ECHINOCHLOA							
E. frumentacea, Anonymous (3)		10.0	11.0	1.7	65.1	8.0	4.2
E. frumentacea, Porteres (29a)		8.4	9.5	2.5	77.6		1.25

APPENDIX 8. MINERAL CONTENT IN MILLETS AND OTHER SELECTED CEREALS (Aykroyd et al. 1963, pp. 83–84)

Name of foodstuff	Per 100 grams edible portion															
	Calcium, mg.	Magnesium, mg.	Oxalic acid, mg.	Phosphorus: Total (a) mg.	Phosphorus: Phytin (b) mg.	Phosphorus: (b) as per cent of (a)	Iron: Total (c) mg.	Iron: Ionisable (d) mg.	Iron: (d) as per cent of (c)	Sodium, mg.	Potassium, mg.	Copper, mg.	Sulphur, mg.	Chlorine, mg.	Acid base balance ml N/10 solution: Acid	Acid base balance ml N/10 solution: Base
1 Pearl millet	42	125	21	269	141	52	14.3	4.4	31	10.9	30	0.55	147	39	56	--
2 Foxtail millet	31	120	0	290	197	66	12.9	2.5	19	4.6	250	0.55	171	37	99	--
3 Proso millet	14	73	0	206	83	40	11.5	1.7	15	8.2	113	0.28	157	19	136	--
4 Finger millet	344	191	0	283	209	74	17.4	0.5	3	11.0	408	0.59	160	44	--	161
5 Japanese millet	20	--	--	280	--	--	2.9	--	--	--	--	--	--	--	--	--
6 Kodo millet	27	112	0	188	135	72	31.1	0.6	2	4.6	144	0.87	136	11	38	--
7 Little millet	17	60	0	220	57	26	10.0	0.7	7	8.1	129	0.42	149	13	116	--
8 Sorghum	25	140	10	222	172	77	5.8	1.4	24	7.3	131	1.78	54	44	27	--
9 Rice-parboiled, milled	9	38	1	143	83	58	4.0	1.4	35	10	117	0.33	79	13	72	--
10 Wheat-whole	41	139	8	306	238	80	4.9	2.5	51	17.1	284	0.49	128	47	77	--
11 Maize-dry	10	144	6	348	306	85	2.0	0.9	45	15.9	286	0.19	114	33	101	--

APPENDIX 9. PROPORTIONATE CONTENT OF MINERALS IN SOME SORGHUM AND MILLET GRAINS OF DIFFERENT SOURCES (after Adrian and Jacquot, 1963)

	Ca %	P %	Ca/P %	K %	Na %	K/Na %	Fe %
SORGHUM							
Nicholls (28)	1.25	14.0	0.09				
Thebaud (33)	1.55	20.9	0.075				0.52
FAO (14)	1.95						0.21
Baird ( )	1.50	18.8	0.08	22.5	0.88	25.5	1.10
Fournier ( )	1.0	13.4	0.075	14.5	0.50	29.0	0.53
Adrian (2) echantillons indigenes	1.35	18.2	0.075	23.2	3.0	7.8	
Adrian (2) echantillons de station	1.35	22.0	0.06	20.6	5.4	3.8	
PENNISETUM							
P. glaucum, FAO (14)	1.65						(0.24)
P. glaucum, Thebaud (33)	1.05	11.5	0.09				
P. typhoideum, Rao (32)	2.05	17.5	0.12				0.50
P. typhoideum, Nicholls (28)	0.80	11.2	0.07				
P. nigritarium, Adrian (2)	2.6	21.4	0.12	22.2	6.5	3.4	
P. pycnostachyum, Adrian (2)	1.6	20.0	0.08	23.8	7.3	3.2	
indigenes, Adrian (2)	1.0	22.5	0.045	21.0	4.0	5.3	

APPENDIX 9 – continued

PANICUM							
P. miliaceum, Haskins (17)	0.50	9.6	0.05	9.3	1.05	8.9	
P. miliaceum, Randoin (31)	0.41	9.6	0.045	8.5	2.5	3.4	
P. miliaceum, Nicholls (28)	0.85	12.0	0.07				
ELEUSINE							
E. coracana, FAO (14)	12.1						0.14
E. coracana, Nicholls (28)	11.7	12.6	0.93				
E. coracana, Kurien (22)	12.0	8.2	1.45				
E. coracana, Gayte-Sorbier (16)	14.6	10.5	1.40				
SETARIA							
S. italica, FAO (14)	1.1						0.13
S. italica, Nicholls (28)	0.85	9.3	0.09				
PASPALUM							
P. longiflorum, Thebaud (33)	1.0	4.5	0.22				0.11
P. longiflorum, Nicholls (28)	2.7	22.5	0.12				
DIGITARIA							
D. exilis, Lanza (23)		7.2		6.7	0.42	16.0	
D. ibirua, Lanza (23)		6.7		7.5	0.42	17.8	

APPENDIX 10. VITAMIN CONTENT IN MILLETS AND OTHER SELECTED CEREALS (Aykroyd et al. 1963, pp. 114–115)

Name of foodstuff	Vitamin A value, I.U.	Thiamine mg.	Riboflavin mg.	Nicotinic acid, mg.	Vitamin C mg.	Biotin, ug.	Choline, mg.
1. Pearl millet	220	0.33	0.16	3.2	0	--	--
2. Foxtail millet	54	0.59	0.08	0.7	0	--	--
3. Proso millet	0	0.20	0.18	2.3	0	--	74 8
4. Finger millet	70	0.42	0.10	1.1	0	--	--
5. Japanese millet	0	0.33	0.10	1.7	0	--	--
7. Little millet	0	0.30	0.09	3.2	0	--	--
8. Sorghum	79	0.37	0.28	1.8	0	--	--
9. Rice-parboiled, milled	0	0.21	0.09	3.8	0	--	--
10. Wheat-whole	108	0.45	0.12	5.0	0	--	--
11. Maize-dry	1,502	0.42	0.10	1.4	0	--	--

APPENDIX 11. COMPOSITION OF LIPIDS IN MILLETS, SORGHUM AND MAIZE GRAINS FROM DIFFERENT SOURCES (after Adrian and Jacquot, 1964)

In parts per 100	Maize	Sorghum			*Setaria italica*		*Panicum miliaceum*	
	ECKEY (13)	FRANCIS FRIEDEMANN (15)	HILDITCH (18)	ECKEY (13)	HILDITCH (18)	ECKEY (13)	HILDITCH (18)	ECKEY (13)
Unsaponifiable	0.8-2.9	1.7		1.7-3.2		2.1-2.8		3.3
Total fatty acids	93.0-95.0					95.5		
Acids-volatile		0.7						4.3
Acids saturated	12.0-18.0	8.5		10.0-15.0				11.5
in C_{14}			0.2					
myristic	0.1-1.7			0.0-1.0		0.6		
palmitic	8.0-12.0		6.0-10.0	6.0-10.0	11.1	10.9		
Stearic	2.5-4.5		3.0-6.0	3.0-6.0	14.7	14.7	12.0	
in C_{24}-C_{22}				traces		8.0		
Acids unsaturated		83.0						
hexadecenoic	0.2-1.6		0.1	0.0-1.0				
oleic	19.0-49.0		35.0-47.0	30.0-47.0	21.8	21.8	24.5	25.8
linoleic	34.0-62.0		41.0-53.0	40.0-55.0	38.2	38.2	58.0	50.6
linolenic	0.0-2.9			0.0-1.0		6.4	5.5	7.8
Index of acid	2-6			4		14-52		13
Index of saponification	187-193	194		181-191		160-193		191.5
Index of iodine	109-133	110		108-122		105-132		129
Index of thiocyanogein	71-77			77				80
Index of dehyroxyl	8-12			17		32-34		17
Index of R. M.	>0.5					0.43-0.48		1.76
Index of Polenske	>0.5					1.3-1.4		
Index of Hehner	92-94					94-95		
Index of refraction								
nD 40°	1464-1468					1471		1458
nD 20°	1470-1474			1468-1472				

APPENDIX 12. ESSENTIAL AMINO ACIDS IN MILLETS AND OTHER SELECTED CEREALS (after Aykroyd et al., 1963–p.137; and Adrian and Jacquot, 1964)

	Approximate total protein percent	Essential amino acids (grams per 100 grams protein)										
		Arginine	Histidine	Lysine	Tryptophan	Phenylalamine	Cystine	Methionine	Threonine	Leucine	Isoleucine	Valine
FAO reference protein	..	..	..	4.32	1.44	2.88	2.08	2.88	2.88	4.96	4.32	4.32
1. Pennisetum: Aykroyd	12.31	7.52	2.56	3.68	1.44	3.68	2.08	2.08	3.36	9.28	4.96	5.44
Adrain-Jacquot		4.80	2.15	3.10	1.90	4.35	1.75	2.10	3.70	9.0	4.50	5.50
2. Setaria: Aykroyd	10.75	7.04	3.84	2.56	0.80	5.28	..	3.52	3.52	13.92	5.60	5.92
Adrian-Jacquot		3.90	2.20	1.80	1.26	5.55	1.35	2.80	3.0	14.0	6.65	5.85
3. P. miliaceum: Aykroyd	6.44	1.12	0.48	4.16	0.96	--	..	2.88	1.28	13.44	6.24	6.88
Adrian-Jacquot		4.65	1.90	1.85	0.55	4.75	..	2.25	3.40	10.85	6.65	6.05
4. P. miliare: Aykroyd	11.00	4.64	1.92	1.76	0.64	4.80	--	2.24	3.36	10.88	6.72	6.08
5. Eleusine: Aykroyd	6.31	3.84	0.96	2.72	1.28	2.88	3.20	3.68	2.08	7.68	4.32	6.56
Adrian-Jacquot		3.40	1.20	2.55	1.15	3.45	2.60	2.75	3.80	7.70	4.50	5.70
6. Paspalum: Aykroyd	6.75	4.48	1.92	3.20	0.48	5.12	--	2.40	3.20	11.20	7.04	6.72
Adrian-Jacquot		4.10	1.90	2.45	0.90	6.70	2.80	3.80	3.90	9.30	5.25	5.95
7. Digitaria: Adrian-Jacquot		3.30	2.20	1.90	--	6.80	2.20	3.0	3.30	11.80	4.30	5.20
8. Eragrostis: Adrian-Jacquot		3.50	2.15	3.10	1.30	4.90	2.50	2.8	3.30	7.70	4.10	6.25
9. Sorghum: Aykroyd	11.75	6.24	2.40	3.20	0.48	4.16	2.40	2.24	3.04	10.40	4.80	4.80
Adrian-Jacquot		4.35	2.55	2.65	0.95	4.60	1.90	1.70	3.30	13.4	4.90	5.50
10. Rice-parboiled, milled: Aykroyd	6.13	8.00	1.28	3.36	--	5.60	1.28	1.28	3.36	--	--	5.44
11. Wheat-whole: Aykroyd	10.75	5.28	1.44	2.24	1.12	5.28	2.24	1.92	2.56	6.56	3.52	4.00
12. Egg: Adrian-Jacquot		6.4	2.60	7.05	1.53	5.85	2.25	3.65	4.9	9.3	7.0	7.25

APPENDIX 13. VARIATION IN THE AMINO ACID COMPOSITION OF GRAIN PROTEINS FROM SEVERAL SPECIES OF SORGHUM AND MILLETS (from Adrian and Jacquot, 1964). (Given in grams per 100 grams of protein)

	Source of Analyses	Number of Analyses	Arginine	Cystine	Histidine	Isoleucine	Leucine	Lysine	Methionine	Phenylalanine	Threonine	Tryptophane	Valine
SORGHUM													
Kuppuswamy (21)	India	6	5.7		2.35	4.65	10.9	2.9	1.8	4.05	2.9	0.75	5.0
Kurien (22)	India	4	6.3		1.5	6.1	13.1	3.2	1.6	5.2	3.9	1.2	5.8
Balasubrahmanian (4)	India	6			3.4	5.9	12.8	3.4	1.65	5.1		1.2	5.9
Williams (34)	U. S. A.		3.2		1.8	5.2	13.2	2.6	0.5	4.6	3.2	1.0	4.7
Baumgarten (6)	U. S. A.		3.4		2.5	5.9	15.2	2.5	0.8	5.1	2.5	0.8	5.9
Adrian (2) indigenous	Senegal	4	3.2	2.05	2.1	5.0	12.0	1.8	2.8	3.95	2.05	1.15	4.8
selection	Senegal	13	3.5	1.6	2.15	4.95	12.5	2.35	2.75	4.65	3.7	1.1	4.85
Busson (8) minimum	Senegal	12	3.8	1.7	2.0	3.8	12.9	1.9	1.6	4.8	3.0	1.0	5.1
maximum			4.9	2.3	2.8	4.3	15.0	2.7	2.3	5.6	3.7	1.2	5.7
hybrids	U. S. A.	13	4.75		3.30	4.7	14.2	2.95	1.50	4.4	3.9	0.7	5.9
Bressani (7) varieties	U. S. A.	10	4.70		3.30	4.7	14.6	3.0	1.75	4.3	3.8	0.7	6.1
indigenous	Guatemala	2	4.55		3.15	4.65	14.6	2.65	1.90	3.8	3.8	0.6	6.1
PENNISETUM													
P. glaucum, Jansen (19)	U. S. A.	1	3.5	3.2	2.1	3.1	7.3	2.9	1.35	3.45	2.5	1.6	4.5
P. pycnostachyum, Busson (8)	Senegal	17	5.6	2.5	2.6	4.2	9.3	3.8	2.4	4.8	4.1	1.9	5.7

APPENDIX 13 – continued

P. pycnostachyum, Adrian (2)	Senegal	4	3.8	1.25	1.8	4.85	8.7	2.6	2.2	4.75	5.5	2.1	5.2
P. nigritarium, Adrian (2)	Senegal	2	5.1	1.25	2.35	3.0	8.2	2.65	2.70	5.05	4.2	2.35	6.2
P. typhoideum, Kuppuswamy (21)	India	2	7.5		2.5	4.95	9.4	3.75	2.1	3.7	3.3	1.5	5.5
P. typhoideum, Balasubrahmanian (4)	India	2			1.75	5.9	9.5	3.8	1.8	4.3		1.9	6.3
P. typhoideum		1	4.7	1.1	2.1	4.9	11.3	2.8	2.1	5.0	3.8	2.0	6.0
indigenous, Adrian (2)	India	7	3.6	1.25	2.0	4.95	8.4	2.7	2.35	3.90	2.65	1.75	4.35
PANICUM													
P. miliare, Ramachandran (30)	Indes	1	4.65		1.9	6.65	10.85	1.85	2.25	4.75	3.4	0.55	6.05
ELEUSINE													
E. coracana, Kuppuswamy (21)	Indes	2	3.75		0.9	4.25	7.7	2.55	3.75	3.0	3.4	1.3	6.5
E. coracana, Balasubrahmanyan (4)		3			1.45	6.5	9.65	3.4	2.9	4.3		1.55	6.75
E. coracana, Gayte-Sorbier (16)	Afrique	1	4.5	2.6	2.2	4.4	9.5	2.9	3.1	5.2	4.2	1.2	6.6
SETARIA													
S. italica, Kuppuswamy (21)	Indes	3	5.9		3.3	6.3	14.8	2.5	3.2	5.75	5.35	0.8	6.25
S. italica, Mangay (25)	U.S.A.	1	2.3	1.35	1.2	6.05	10.5	0.75	2.4	4.2	2.65	2.0	4.45
S. italica, Ramachandran (30)	Indes		3.55		2.1	7.6	16.7	2.15	2.8	6.7	3.1	1.0	6.9

APPENDIX 13 – continued

PASPALUM													
P. scrobiculatum, Kuppuswamy (21)	Indes	2	4.4		1.9	6.5	9.6	2.7	3.0	8.0	3.8	0.7	6.45
P. scrobiculatum, Ramachandran (30)	Indes	1	4.05		1.8	5.3	8.55	2.1	2.85	6.95	3.85	0.65	5.6
P. longiflorum, Carbiener (10)	Afrique	1	3.8	2.8	2.1	4.0	9.8	2.6	5.6	5.1	4.0	1.4	5.8
DIGITARIA													
D. iburua, Lanza (23)	Afrique	1	3.3	2.2	4.3	4.3	11.8	1.9	3.0	6.8	3.3		5.2
ERAGROTIS													
E. Abyssinica, Jansen (19)		6	3.5	2.5	2.15	4.1	7.7	3.1	2.8	4.9	3.3	1.3	5.25

APPENDIX 14. EFFECT OF MILLING MAIZE, SORGHUM, PENNISETUM AND ELEUSINE GRAINS ON THE NUTRITIVE VALUES OF THEIR CORRESPONDING FLOURS (after Adrian and Jacquot, 1964)

	Maize			Sorghum			Pennisetum			Eleusine		
	Content per 100 grams of grain	Correspon-ding flour	% lost in milling	Content per 100 grams of grain	Correspon-ding flour	% lost in milling	Content per 100 grams of grain	Correspon-ding flour	% lost in milling	Content per 100 grams of grain	Correspon-ding flour	% lost in milling
Dry matter (g)	100	55	45	100	66	34	100	75	25	100	80	20
Proteins (g)	8.45	4.75	44	11.2	7.75	31	8.6	5.7	34	11.9	9.6	19
Lipids (g)	4.9	0.8	84	3.95	2.05	48	5.7	3.15	45	2.2	1.85	16
Glucoides (g)	71.7	49.1	31	76.5	54.3	29	76.9	63.1	18	84.7	67.0	21
Crude cellulose (g)	1.72	0.16	93	1.30	0.46	65	2.30	0.52	77	3.1	2.65	14
Ash (g)	1.25	0.16	87	2.81	1.99	29	4.07	2.91	29	3.23	3.09	4
Calcium (mg)	10.8	3.8	65	22.5	10.5	53	26	15	42	300	240	20
Phosphorus (mg)	217.0	25.5	88	224.5	116.0	48	290.5	151.5	47	245	175	29
Iron (mg)	10.0	2.75	73	15.6	11.9	24	42.0	34.5	18	11	--	--
Thiamine (g)	270	22	92	305	205	33	275	165	40	360	270	27
Riboflavin (g)	115	11	90	92	39.5	58	305	195	36	190	130	32

APPENDIX 15. COMPOSITION OF DIFFERENT STAGES OF FORAGE FROM SEVERAL SPECIES OF MILLETS, SORGHUMS AND OTHER GRASSES (after Morrison, 1950 and van Wyk et al., 1955)

A. Analysis of dried material expressed in percent of total including residual moisture, USA (Morrison, 1950)

Species/Variety		Parts per 100 fresh material									
Common name	Scientific name	Form/ stage	Dry matter	Proteins	Lipids	Crude cellulose	N. FE extract	Ash	Calcium	Phos-phorus	Pot-assium
Atlas sorghum	(S. vulgare)	stover	85.0	4.0	2.0	27.9	44.2	6.9	0.34	0.09	
Feterita	(S. caudatum)	fodder	88.0	8.0	2.1	18.7	51.5	7.7	0.30	0.21	
Feterita	(S. caudatum)	stover	86.3	5.2	1.7	29.2	41.9	8.3			
Hegari		fodder	86.0	6.2	1.7	18.1	52.5	7.5	0.27	0.16	
Hegari		stover	87.0	5.6	1.8	28.0	41.7	9.9	0.33	0.08	
Johnson grass	(S. halepense)	hay	90.1	6.5	2.1	30.4	43.7	7.4	0.87	0.26	1.22
Kaffir	(S. caffrorum)	fodder	90.0	8.7	2.6	25.5	44.2	9.0	0.35	0.18	1.53
Kaffir	(S. caffrorum)	stover	90.0	5.5	1.8	29.5	44.3	8.9	0.54	0.09	
Milo	(S. vulgare)	fodder	88.5	8.0	3.3	21.9	48.4	6.9	0.35	0.18	
Milo	(S. vulgare)	stover	91.0	3.2	1.1	29.1	48.1	9.5	0.58	0.11	
Sweet sorghum	(S. bicolor)	fodder	88.8	6.2	2.4	25.0	48.1	7.1	0.34	0.12	1.29
Sudan grass	(S. sudanense) {before flowering	hay	89.3	8.8	1.6	27.9	42.9	8.1	0.36	0.26	1.30
Sudan grass	(S. sudanense) {before flowering	hay	89.6	11.2	1.5	26.1	41.3	9.5	0.41	0.26	
Sudan grass	(S. sudanense) flowering	hay	89.2	8.4	1.5	30.7	41.8	6.8			
Sudan grass	(S. sudanense) formed	hay	89.5	6.8	1.6	29.9	44.4	6.8	0.27	0.19	
Foxtail millet	(Setaria italica)	hay	87.6	8.2	2.7	25.3	44.7	6.7	0.29	0.16	1.70
Proso	(Panicum miliaceum)	hay	90.3	9.3	2.2	23.9	47.6	7.3			
Japanese millet	(Echinochloa frumentacea)	hay	86.8	8.3	1.6	27.7	40.8	8.4	0.20		2.10
Pearl millet	(Pennisetum typhoideum)	hay	87.2	6.7	1.7	33.0	36.8	9.0			
Napier grass	(Pennisetum purpureum)	hay	89.1	8.2	1.8	34.0	34.6	10.5			

APPENDIX 15 – continued

B. Analysis of fresh material expressed in percent of total including moisture, USA (Morrison, 1950)

Species/variety	Form/stage	Dry matter	Proteins	Lipids	Crude fiber	N. F. E. extract	Ash	Calcium	Phosphorus	Potassium
Durra	fodder	22.4	2.0	0.6	6.2	11.8	1.8			
Kaffir	fodder	23.6	2.4	0.7	6.6	12.0	1.9	0.09	0.05	0.40
Kaffir	headed	19.9	1.6	0.4	6.5	10.1	1.3			
Sweet sorghum	fodder	24.9	1.5	1.0	7.0	14.0	1.4	0.09	0.03	0.36
Sudan grass	pasture	21.6	3.3	0.6	5.6	10.2	1.9	0.12	0.10	
Sudan grass	flowering	23.4	1.9	0.4	8.4	10.3	2.4	0.09	0.07	
Sudan grass	grains formed	28.5	1.7	0.5	9.6	14.6	2.1	0.09	0.06	
Foxtail millet		29.9	2.9	0.8	9.4	14.3	2.5	0.10	0.06	0.58
Japanese millet	fodder	21.7	1.7	0.6	6.8	11.0	1.6	0.11	0.07	0.52
Japanese millet	pasture	21.3	2.8	0.5	5.6	10.0	2.4			
Proso		24.7	2.0	0.6	7.4	12.9	1.8			
Pearl millet	pasture	20.6	2.1	0.6	6.4	9.6	1.9			
Napier grass		21.9	1.1	0.3	9.0	8.9	2.6	0.08	0.07	

APPENDIX 15 – continued

C. Analysis of forage on moisture free basis expressed in percent-South Africa (van Wyk *et al.*)

Species/Variety	Proteins	Lipids	Crude fiber	N. F. E. extract	Ash	Calcium	Phosphorus	Potassium
HAY								
Boer millet (Setaria italica)	9.1	2.0	39.6	40.8	8.5	0.36	0.13	1.45
Colombus grass (Sorghum almum)	9.8	2.8	31.9	45.9	9.6	0.48	0.23	1.56
Japanese millet (Echinochloa frumentacea)	15.5	3.0	26.2	44.3	11.0	0.50	0.24	2.17
Napier grass (Pennisetum purpureum)	9.6	1.8	38.9	38.9	10.9	0.44	0.18	2.09
Babala (Pennisetum typhoideum)	7.2	1.8	41.6	40.8	8.7	0.49	0.17	1.60
Kazungala (Setaria kazungala)	8.4	1.9	40.9	40.3	8.5	0.29	0.11	2.07
Sudan grass (Sorghum sudanense)	8.7	1.95	35.2	45.4	8.8	0.40	0.18	1.39
PASTURES								
Babala (P. typhoides): young	17.7	3.2	21.1	44.7	13.4	0.66	0.32	2.20
Babala (P. typhoides): mature	6.2	1.4	31.8	50.6	10.1	0.40	0.26	1.40
Colombus: young	14.6	4.7	27.0	43.5	10.3	0.60	0.19	1.74
Colombus: mature	8.2	3.3	35.2	45.3	8.1	0.50	0.09	1.70
Napier grass: young	17.1	3.7	25.8	34.6	18.8	0.53	0.22	4.38
Napier grass: mature	8.3	2.6	35.1	39.5	14.4	0.35	0.16	3.70
Sudan grass: young	15.4	3.7	23.4	47.7	10.4	0.51	0.26	1.80
Sudan grass: mature	8.0	1.6	32.1	49.2	9.1	0.35	0.20	1.00
ENSILED								
Babala (P. typhoides)	11.4	5.2	32.3	42.2	8.9	0.57	0.20	1.45
Bana (P. typhoideum x P. purpureum)	5.2	2.9	43.9	34.6	13.4	0.64	0.16	1.58
Napier grass	7.1	2.5	39.2	37.3	13.9	0.69	0.15	3.02

The International Crops Research Institute for the Semi Arid Tropics receives support from a variety of donors, governments, foundations, etc. including IBRD, IDRC, UNDP, USAID, etc.

The responsibility for all aspects of this publication rests **with the** International Crops Research Institute for the Semi-Arid **Tropics.**

PUBLISHED BY
INTERNATIONAL CROPS RESEARCH INSTITUTE
FOR THE SEMI-ARID TROPICS
1-11-256, Begumpet
Hyderabad-500016 (A P) India.