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AGRICULTURAL RESEARCH CORPORATION

WESTERN SUDAN AGRICULTURAL RESEARCH PROJECT

THE GOVERNMENT OF SUDAN
UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT
THE WORLD BANK
CONSORTIUM FOR INTERNATIONAL DEVELOPMENT
WASHINGTON STATE UNIVERSITY

INCREASING CROP PRODUCTIVITY IN WESTERN SUDAN - RESULTS OF SELECTED AGRONOMIC TRIALS

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FOREWORD

Western Sudan typically produces about 400,000 metric tons, each, of sorghum, millet, and groundnuts plus just over 100,000 tons of sesame, annually (Table 1). This is equivalent to about 20% of the sorghum, 90% of the millet, 50% of the groundnuts and 45% of the sesame produced in Sudan (Table 2). In addition, Western Sudan is a major source of all but one (harricot beans) of the top eleven agricultural commodities (by value) exported from Sudan in 1982 (Table 3). Despite the major contribution of Darfur and Kordofan Regions to the national agricultural output, little attention has been given, till recently, to developing new technology to increase the productivity of farmers in Western Sudan.

The Western Sudan Agricultural Research Project initiated in 1979 is attempting to correct this imbalance by establishing research stations and programs for the Agricultural Research Corporation in El Obeid, Kadugli, Ghazala Gawazat and El Fasher. The Project expanded agronomic research in Kadugli in 1982 and initiated it in El Obeid in 1983. The German Development Assistance Agency, GTZ, working with the Nuba Mountains Agricultural Production Corporation, NMAPC, the Mechanized Farming Corporation, MFC, the Jebel Marra Rural Development Project, JMRDP, and the Western Savannah Development Cor oration, WSDC, have conducted agronomic trials in Western Sudan for a number of years. The results of selected trials conducted by WSDC, GTZ, MFC, JMRDP, and WSARP

over the last few years make up the bulk of this report. Additionally, results obtained by Doxiadis Associates, which conducted trials in the El Obeid area from 1963-1965, and ARC trials near El Obeid in the early and mid-1970's are included. The report is not meant to be a comprehensive compilation of all the results of agronomic trials conducted in Western Sudan, but indicative of the information that has been gathered on means of increasing crop productivity in the area. WSARP would be pleased to receive the results of additional trials conducted in Kordofan or Darfur Regions that any of the readers consider relevant. Those interested in some of the broader aspects of development in Western Sudan are referred to a summary of the WSARP/ARC Regional Planning Workshops (WSARP Publication 20).

CROP RESPONSE TO FERTILIZER

Introduction

The yield response of crops grown under rainfed conditions to the application of fertilizer is dependent upon the crop and the cultivar planted, the amount and type of fertilizer added, the time of application, the method of placement, the soil type, and the availability of water (rainfall). Consequently, crop responses to fertilizer vary considerably from season to season and location to location. Selection of cultivars responsive to fertilizer and appropriate fertilizer formulation, placement and timing are critical to achieving the desired results, i.e. increased crop productivity (where crops are used for multiple purposes, as in Western Sudan, this may mean increases in both grain yield and stover or haulm growth).

Fertilizer should be incorporated into or placed in the soil adjacent to the plants so it is easily accessible to plant roots. Broadcasting of fertilizer is inadvisable since that which falls far from the widely-spaced plants will not only be lost to the plants, but will also tend to promote weed growth.

The data given in the following tables give an indication of the most promising direction for introducing fertilizer into Western Sudan. However, these data need to be substantiated in replicated trials on farmers' fields and at experiment stations. This testing should be done in combination with

other improved technologies to assure widespread success on producers' field throughout Western Sudan. A summary of the nomenclature for fertilizer application rates used in Sudan and equivalencies are given in the Appendix.

Southern Kordofan

The Senior Agronomist of the Mechanized Farming Corporation began conducting adaptive agronomic research trials in the 1980/81 season at the El Fuda Development Center near the western border of southern Kordofan (10°28 N, 27°45 E) on the rail line connecting Babanusa and Wau. Baroya, sandy loam soils are interlaced with loamy sand Qoz soils in this locale. Experiments were planted primarily on the Qoz soils. Fertilizer trials were initiated at El Fuda in the 1981/82 cropping season. The response of millet, groundnuts, sesame and sorghum to several levels of NPK was recorded. The treatments that produced the most consistent results are given in Tables 4,5,6 and 7.

Millet yield was increased the most by treatments containing phosphorus solely or in combination with other fertilizers. The highest benefit to cost ratio was for P applied alone in 1981/82; N plus P in 1983/84; and N plus P and K in 1982/83. N applied alone produced erratic results (Table 4).

The results for groundnuts were not as consistent as those for millet. In 1983/84, P applied by itself had the highest

benefit to cost ratio. In 1981/82, N applied solely produced the highest benefit to cost ratio. In 1982/83, N, P and N plus P all had high benefit to cost ratios (Table 5).

The benefit to cost ratio for fertilizer induced yield increases for sesame were lower than for any other crop. Only P applied alone in 1982/83 resulted in a benefit to cost ratio above two (i.e. 3.4) (Table 6).

Sorghum yields were increased by the addition of either nitrogen or phosphorus solely or in combination. However, only in 1983/84 was the benefit to cost ratio of the combined application greater than or equal to that of the individual doses (Table 7).

The response of crops planted on the cracking clay, vertisol soils in the Nuba Mountains (near Kadugli) to the application of nitrogen alone has not been impressive (Tables 8,9,10). However, combined application of nitrogen and phosphorus more than doubled sorghum grain yield and increased stover weight by 23% (Tables 11,12).

Northern Kordofan

In 1963-1965, Doxiadis Associates conducted agronomy trials near El Obeid at Kaba on the clayey, pediplain (Gardud) soils and at Umm Higlig on the sand sheet (Gum-Qoz) soils. An excerpt from their final report concerning fertilizer trial results follows:

> "483. The obtained results from the above trials carried out on gardud and on Qoz soils gave the following indications:
>
> a. Nitrogen alone or Phosphorus alone are ineffective in increasing the yields but when applied together the increase is statistically significant.
>
> b. Nitrogen and Phosphoru fertilizer at the higher tried rates of 40 kg/ha N_2 80 kg/ha P_2O_5, respectively cause highly significant increases in the yields of both total air-dry matter and grain, in comparison with the control.
>
> c. Potassium does not cause any significant increase in the yields and has no interaction with Nitrogen and/or Phosphorus.
>
> d. The quantity of yearly rainfall and especially its distribution is an important factor on which the reaction of the plants to the fertilizer application greatly depends.

e. The percent increase in yields due to fertilizer application varied from 10 to 110 percent for sorghum, 25 to 228 percent for sesame and 2 to 50 percent for groundnuts according to the rates of fertilizer applied, the amount of yearly rainfall and the variety.

484. In general the results obtained from the trials dealing with fertilizers were very encouraging. It showed that the crops grown on Sand Sheet or on Clayey, Pediplain soils can perform better and yield higher if treated with NP fertilizer.

485. Figure 68 (Figure 1 in this report) shows the maximum yields of sorghum, sesame and groundnuts obtained from fertilizer trials at the two Experiment Sites of the Project Kaba and Umm Higlig and maximum yields obtained by local farmers under local cultivation practices from fields located around the two Experiment Sites.

486. The data collected from the fertilizer trials conducted by the Project, although insufficient to determine the optimum rates of fertilizer, have, however, presented a definite indication that with the application of fertilizer an increase in yields is to be expected. Calculation made to determine whether the use of fertilizers would be economic with responses obtained from the fertilizer trials, showed that the gross income of the local farmer can be increased by 9.3% to 180.0% if fertilizer is applied (Table 9) (Table 13 of this report). The data shown in the Table should be considered only as indicative since, as it is known, the optimum economic use of fertilizers may be found only after years of experimentation.

"487. Specific fertilizer recommendations are made only when sufficient data are accumulated to enable a response curve or surface to be calculated. Such a curve or surface can show what economic return can be expected by the application of fertilizer. Nevertheless, provisional recommendations can be made when preliminary trials indicate that economic return is to be expected by fertilizer application even though there is insufficient data to determine the optimal rates of fertilizers.

488. Fertilizer experiments conducted by K.A. Watson in northern Nigeria from 1949 to 1962 gave almost the same results with the ones obtained from the fertilizer trials carried out at the two Experiment Sites of the Project. Watson states the

> optimal dressing for the sorghum and groundnuts for conditions similar to the ones existing in the Project Area is 30 kg of ammonia sulfate plus 30 kg of P_2O_5 per acre." (8)

Fertilization with nitrogen and phosphorus combined at Kaba and Umm Higlig in 1964 increased sorghum yields by 50%, doubled mungbean yields and raised guar yields by 20% (Table 14).

The differences in yield response to fertilizer caused by the absence or presence of a single rain storm is evident in the 1983 trial results with sorghum and millet at Kaba and Banjadeed (Tables 15,16). The increase of sorghum yields at Kaba were not as great in 1983 as reported in the 1964 trials at the same location which may be attributed to a lower level of fertilizer applied as well as differences in cultivars, rainfall regimes and possibly plant spacing.

The ARC conducted some trials at Alloba, near El Obeid, in the 1970/71 season. Sesame cultivar A-5-9 showed a significant yield response to the addition of nitrogen fertilizer and wider spacing (Table 17).

> "That nitrogen significantly increased seed yield at wider spacing, but, not at closer spacing could be treated as an unusual result had not soil moisture been a limiting factor. Nitrogen by increasing plant size aggravated soil moisture conditions more at the closer spacing than at the wider spacing." (29)

Nitrogen (urea) applied alone on groundnuts planted in El Obeid in 1983 increased haulm growth by 50% but had little effect on pod yield (Table 18).

Southern Darfur

The results of fertilizer trials conducted by the Western Savannah Development Corporation at Umm Rakuba on Qoz Ma'aliya soils and at Dimsu on Qoz Dango soils demonstrate the yield response of sorghum and sesame to a combined application of nitrogen and phosphorus (Tables 19,20,21).

The response of grain crop (groundnuts, cowpeas and sesame) and forage crop (cowpeas and sirato) yields to fertilizer, evaluated in Umm Rakuba in 1983, showed that the yield increase to a combined nitrogen and phosphorus application was greater than that of either applied alone. Forage yields were doubled and grain yields were increased by 30% with the application of NP (Table 22).

In 1983, the yield of cereal crops (sorghum and millet combined) was increased in the Jebel Marra area by the addition of triple super phosphate. Cereals on upper terrace soils were most responsive to TSP. Their yields were increased by 75% with the application of an amount of phosphorus equivalent to 18kg/ha P_2O_5. The yields of crops planted on alluvial soils without phosphorus, were double those on upper terrace soils. Thus the absolute yield

increase to the application of TSP (at 18kg/ha P_2O_5 level) was greater on the alluvial soils than on terraces, but, the percentage increase was less (Table 23). The benefit to cost ratio for the addition of phosphorus to cereals on upper terrace and alluvial soils in the Jebel Marra Project area in 1983 average 10.1:1 for the lower rate of application of TSP (equivalent to 18kg/ha of P_2O_5) and 3.6:1 for the higher rate, equal to 55kg/ha of P_2O_5 (Table 24).

The yield response of millet to phosphorus, applied as triple super phosphate, was recorded in 15 trials conducted in Dimsu and Umm Rakuba in the period 1976-1983. Millet yields were doubled by the application of TSP at the rate of 20kg/ha P_2O_5 (44kg/ha TSP) (Table 25). A preliminary assessment of the economics of TSP use on millet in S. Darfur indicates a benefit/cost ratio of 4:1 might be expected at this rate of fertilizer application (Table 26). It should be noted that in only 3 of the 15 trials the effect of phosphorus was not significant. A similar benefit to cost ratio was calculated for the application of TSP to sorghum in the Jebel Marra Rural Development Project area in 1982 (Table 27).

The application of nitrogen alone increased in 1983 millet yields in Nyertete by less than 5%, but, when combined with pre-planting plowing, yields were raised by nearly 50% (Table 28). However, in 1982 the benefit cost ratio for urea applied to millet in the Jebel Marra was only 1.5:1. Only one of the

11 millet trials conducted in the Western Savannah Development Corporation area from 1976-1983 showed a significant response to nitrogen and that was to depress grain yields. Nitrogen would be expected to at least increase vegetative growth, but that has not been demonstrated either (10).

The response of groundnuts to phosphorus has been inconsistent. No response to nitrogen or potassium alone or in combination with phosphorus has been found.

Conclusions

There is considerable evidence indicating the positive response of cereal, legume and forage crops to phosphorus and combined phosphorus and nitrogen fertilizer applications when conditions are suitable for healthy plant growth. However, additional technical and economic data are needed before specific application levels can be widely recommended to farmers in Western Sudan.

The yield response to N, applied as urea, has been less consistent and less dramatic than the crop response to P. Urea is more susceptible to loss by volatilization, especially under rainfed conditions (10). Thus, it may be influenced more by the means of application and the conditions under which it is applied. For example, in the 1983 trial with millet in Nyertete, the yield response to N was increased from 5% to 50% when the land was cultivated prior to planting.

Perhaps other forms of phosphate or fertilizers containing both nitrogen and phosphorus would be more suitable for application in Western Sudan. There may be a way to formulate fertilizer so that it is not released until soil moisture levels are sufficient for germination, plant establishment and adequate growth.

Since transportation costs to and within Sudan will comprise a large potion of the farm-gate price, fertilizers selected for use by farmers in Western Sudan should be highly concentrated. However, they must be in a form that is suitable to the area and relatively easy for the farmers to apply. It is suggested that the International Fertilizer Development Center, IFDC (address given below) be consulted with regard to the best fertilizer formulation to import for use on the rainlands of Western Sudan, and to ascertain whether Sudan has any phosphorus deposits.

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IMPROVED CULTIVARS

Introduction

Yields of most rainfed crops in Western Sudan have declined more or less steadily since the base period, 1961/62 - 1970/71 (Tables 29,30,31 and 32). Yield levels of millet and sesame in Kordofan have fallen most rapidly. In the last decade millet and sesame yields averaged 54% and 62%, respectively, of the levels observed in the base period. The relative yields of millet and sesame have not dropped as fast in Darfur. The average yields of millet and sesame in Darfur for the decade ending in 1983/84 were 73% and 75% of the base period values. Relative sorghum yields in Darfur were higher than in Kordofan until the 1971/72 - 1980/81 period, after which the relative yields in Darfur fell more rapidly than those in Kordofan. Thus, relative sorghum yields averaged over the latest decade were 70% of the base period levels in Darfur and 80% in Kordofan.

Groundnut yields have declined the least of the four crops, in fact in Darfur they were above base period levels until 1982/83. There was a dip in average Kordofan groundnut yields in the decades ending in 1974-77, since then yields have increased. The recent downward trend in Darfur and the upward trend in Kordofan make the average relative yields in the two Regions about equal (i.e. Kordofan 89%; Darfur 90%).

New genetic stock may help reverse the general downward trend in yields, particularly earlier maturing cultivars that require less water to produce a good yielding crop. Numerous cultivars of crops currently or potentially important to farmers in Western Sudan have been screened by the Western Sudan Agricultural Research Project, the Agricultural Research Corporation, The Mechanized Farming Corporation, the Jebel Marra Rural Development Project and the Western Savannah Development Corporation. Advantage has been taken of the germplasm available from the appropriate International Agricultural Research Centers and Collaborative Research Support Programs, CRSPS. Trials have been conducted with seeds from ICRISAT, INTSOY, IITA, AVRDC, INTSORMIL and the Bean and Cowpea, CRSP.*

---

*	ICRISAT	International Crops Research Institute for the Semi-Arid Tropics.
	INTSOY	International Soybean Program, University of Illinois.
	IITA	International Institute for Tropical Agriculture.
	AVRDC	Asian Vegetable Research and Development Center.
	INTSORMIL	International Sorghum and Millet Program (Sorghum and Millet CRSP).
	CRSP	Collaborative Research Support Program.

These were supplemented with seeds collected from farmers' fields, and local markets in Western Sudan; seeds resulting from ARC cooperative programs with international or regional organizations; seeds from other national organizations in Sudan including the National Seed Administration and the University of Khartoum; plus seeds ordered from commercial firms in the USA, Taiwan, Kenya and Australia. As yet, the results from many of these trials (particularly with horticultural and forage crops) are not available. A few of the results from screening trials of millet, sorghum, groundnuts, sesame, several legumes and horticultural crops are included here to illustrate the progress and problems of finding superior cultivars for farmers in Western Sudan.

Legumes, although not widely planted now, are receiving considerable attention by WSARP and other organizations in Western Sudan, since they produce protein rich grains, highly nutritious forage, and add nitrogen to the soil. They are being evaluated for inclusion in long-term rotation schemes with the intent of shortening or eliminating the fallow period and, thus, stabilizing crop production in a given location. Also, legumes are entered into intercropping trials, primarily with cereals, to reduce soil erosion, suppress noxious weeds and improve productivity per unit area.

Millet

Millet cultivar evaluation trials were conducted by the ARC in Kaba (near El Obeid) in the 1974/75 and 1975/76 seasons. In 1974/75 the plant population of all entries was low due to poor seedling emergence and plant establishment. A local check from Western Sudan had the highest plant population and yield, but, was latest to mature. In 1975/76, the cultivar Faki Abyad from Darfur had the highest yield. Yields of all entries in 1975/76 were remarkably high given the low rainfall, 198mm. Serere 10 LA x Serere 17, from Uganda, ranked third in 1974/75 and second in 1975/76. Ex. Bornu, an entry from Nigeria ranked sixth in 1974/75 and fourth in 1975/76. The local cultivar, Kordofani, was evaluated in the 1975/76 trial, where it ranked tenth out of ten entries (Tables 33 and 34).

The cooperative ARC program with ICRISAT in sorghum and millet crop improvement was responsible for the release in 1982 of a millet cultivar named Ugandi. It originated in Uganda as Serere Composite -2. It yielded well in Kordofan compared to the most popular traditional cultivar, Kordofani, especially in low rainfall years. Ugandi is early maturing, 70-80 days, and has bristles which render some protection against attack by birds, mice and grasshoppers. The INTSORMIL program agronomist in El Obeid found that farmers indicated a preference for Ugandi in 1983 on-farm trials. Consequently, the National Seed Administration is producing more Ugandi seed

for farmers in Western Sudan. The INTSORMIL agronomist reported for the 1984 season.

> "...Ugandi has shown superiority under this year's extremely marginal conditions (average rainfall July-September at 9 sites = 131mm). In five villages it is the only millet from which the farmers were able to harvest seed for consumption. Ugandi escaped the severe drought because of its earliness. Its bristles (hairs) rendered protection against birds. Unbristled types were completely eaten up." (33)

In other 1983 INTSORMIL trials, the millet cultivar Eish Bornu yielded well. It has a compact head that helps it resist attack of burrowing insects and insect larvae and, to a lesser extent, birds and grasshoppers (3).

Eighty millet lines collected locally in the Jebel Marra area were planted in Nyertete in 1982. The highest yielding lines were those that flowered in 67-68 days (9).

> "There is plenty of scope for the selection of earlier maturing material for the wetter parts of the Jebel Marra Project area, but, little scope for even earlier material for the drier parts. Northern Darfur a potential source of early maturity, has very little grain left in it after the droughts of 1982 and 1983." (24)

ICRISAT line ICMS 7817 ranked first out of 14 lines in Kaba in 1983; second out of 21 lines in Nyertete in 1982 and third out of 15 lines in Dimsu in 1983 (Tables 35,36, and 37). Another line from ICRISAT, IVSH 78, ranked second in Dimsu and Kaba in 1983 and fifth in Nyertete in 1982. Both lines out-yielded Kordofani and Ugandi. The local cultivar, Bayuuda (Nyertete), yielded twice as much as the introduced cultivars in the trial in Nyertete in 1982. Also, it was the highest yielding entry

in the National Yield Trial in Nyertete in 1983. Bayuuda (Nyertete) yielded 1374 kg/ha compared to 919 kg/ha for Ugandi and 684 kg/ha for Kordofani (Table 38). The ICRISAT pearl millet breeder improved the purity of Bayuuda, Kori and Wad El Lahaw by eliminating wild types in plantings in El Obeid. Purified Kori and Wad El Lahaw were 7-10 days earlier than the original populations in Umm Rakuba and Dimsu in 1984. Togo, P 8202, ICMV 8211 and Bristled Population were the best entries in the Pearl Millet National Trial planted in Nyertete in 1984. The Bristled Population and Ugandi were generally good at all locations in Western Sudan (Kaba, WSARP El Obeid Farm, Kadugli, Nyertete, Dimsu and Umm Rakuba) in 1984 (35).

An ICRISAT hybrid millet responded well to fertilizer (10 kg/ha of nitrogen and phosphorus) and demonstrated a good yield potential in an unreplicated trial in Banjadeed in 1983 (3).

Sorghum

The ARC screened sorghum cultivars in Kaba, near El Obeid in 1974/75 and 1975/76. Dwarf White Milo was highest yielding in 1974/75, a year with average rainfall, but, it ranked seventh the following year, which had only 198mm of rain. In 1974/75 a number of the Dwarf White Milo plants suffered stem breakage at the upper node and the plots of NES-585, which ranked second in yield contained many off-types. A large number of plants in the 1974/75 trial did not form any heads.

Apparently, the plant population was too dense for the limited amount of rainfall (346mm). Cross 5: 10/7/8 had the highest yield in 1975/76. The population density was still too high in the 1975/76 trials. This coupled with the low rainfall resulted in yields lower than the previous year. Also, the plots were heavily infested with striga. Gadem El Hamam ranked seventh and ninth out of 16 entries in 1974/75 and 1975/76 respectively. Dabar ranked eleventh in 1974/75 and sixteenth the following year (Table 39).

Another sorghum trial was conducted in Kaba in 1975/76 - the FAO Regional Cooperative Trial, with 12 entries. Six of the introduced lines out-yielded the local check cultivar, T.U.B. 7*(Table 40). In the ARC trial at Kaba in the same year, T.U.B. 7 ranked second.

> "The Senegalese variety CE90-16-3 which was comparable to Giza 3 in yield and maturity, was more impressive and uniform. It shows some promise for rain(fed) cultivation. It is also of desirable grain quality. The Egyptian varieties generally showed higher lodging percentage..." (31).

Striga infestation was moderate.

In a planting data experiment conducted in Kadugli in 1979 the cultivar Gadem El Hamam out-yielded the cultivar Dabar by 40% (Figure 2). In other trials in Kadugli, Gadem El Hamam

---

* T.U.B. = Tozi-Umm Benein. It indicates the line originated from an ARC breeding program in East Central Sudan.

yielded 26%, 66%, and 14% more than Dabar in 1979, 1980 and 1982 respectively (Tables 41,42). Based upon this information, early planting of Gadem El Hamam was evaluated by WSARP in a number of on-station and on-farm trials in Kadugli in 1983. In Eastern Sudan, Dabar is preferred by consumers because of its whiter grain and, accordingly, commands a higher market price than Gadem El Hamam. WSARP is seeking to determine whether the same relationship holds true in Western Sudan where Gadem El Hamam has been used primarily for making liquid refreshments.

Dabar and Gadem El Hamam performed well, compared to traditional, longer-maturing cultivars in trials in the vicinity of Jebel Marra in 1982 and 1983 (Tables 43,44). All but 2 of 171 farmers interviewed rated Dabar equal or superior to traditional local cultivars. The farmers preferred it because of its early maturity, higher reliability in poor seasons, good tasting white flour, good yield and resistance to pests and diseases (9). Eight introduced lines in the National Yield Trial (including Dabar) planted in Nankoseh in 1983 had acceptable utilization characteristics for preparation of asiida (Table 45). However, the Jebel Marra Project staff concluded:

> "Neither Dabar nor Gadem El Hamam is really a totally satisfactory answer to the Project's search for improved germplasm. The adaptive Research Division has shown a role for these varieties on soils with less favorable moisture characteristics but the local Fasiik is favored on grounds of both palatibility and yield on alluvial sandy soils."(24)

Several local cultivars have demonstrated a yield potential equal to or greater than introduced cultivars in Kadugli 1979, 1980 and 1982 (Table 41,42). However, the local lines are taller, later maturing, and less tolerant to drought.

Seven cultivars in the National Variety Trial planted in Kadugli in 1983 out-yielded Dabar and Gadem El Hamam. Two lines, SU CR 35:20 and SU CR 40:36, yielded 40% more than Dabar and Gadem El Hamam (Table 46). Fifteen lines in the National Hybrid Trial, planted in Kadugli in 1983, yielded more than the newly-released sorghum hybrid, Hageen Dura #1. The best yielding line produced 1470 kg/ha of grain compared to 1029 kg/ha for Hageen Dura #1 (Table 47).

An ICRISAT introduced cultivar, P898012, a feterita type sorghum, is well adapted to the Gardud soils in the El Obeid area. It is high-yielding and drought tolerant. However, the INTSORMIL agronomist made the following report for the 1984 season near El Obeid:

> "Sorghum heads are a rare sight this year. Nevertheless, wherever some plants were established the hybrid sorghum (Hageen Dura)... has shown better earliness and drought tolerance than the most drought tolerant entry P 898012. On several sites the hybrid had large heads full of seed while P 89012 produced either very tiny heads or in most cases did not head at all." (33)

IS 9830, a cultivar originally included in a screening trial for resistance to striga, prepared by the University of Khartoum and the ARC, does well on the sandy soils near El Obeid. IS 9830 is early maturing. It yielded 325 kg/ha in an

INTSORMIL on-farm trial in Umm Araada in 1983, although it was planted late (in August). IS 9830 was the top yielding line in INTSORMIL trials in Kaba and Banjadeed in 1983 (3). IS 9830, also, is one of the few lines that is infested with striga; the others are Tetron, SRN39 and IS 7271 (23). In comparison, the newly released sorghum hybrid, Hageen Dura #1, becomes heavily infested with striga when planted in fields where striga seed is present.

The highest yielding local sorghum cultivars of a total of 180 collected in the Jebel Marra Rural Development Project area were those that flowered in 88-90 days. The evaluation trial was conducted in Nankoseh on alluvial soil in 1982.

> "The local lines are mostly late maturing, but, are adapted to the favorable moisture conditions of many of the alluvial soils. Even in years of below-average rainfall, highest yields are given by all but the very latest maturing lines in suitable locations. There is very little scope for selection of significantly earlier-maturing lines from within the local material..."

Groundnuts

Barberton is the most widely-planted groundnut cultivar in Western Sudan. It was introduced over 30 years ago from South Africa. As early as 1974/75, its low yield potential relative to other introduced cultivars was demonstrated (Table 48). Poor processing and handling of seed over the years have resulted in the mixing of seed to the extent that it is questionable whether the Barberton that the farmers are planting is representative of the true Barberton. Thus, plans have been made to propagate and purify Barberton germplasm for

distribution to farmers in Western Sudan. The yields for Barberton reported in the following trial results should reflect the cultivar's true yield potential under the given environments, since they were prepared by the head groundnut plant breeder of ARC. Two groundnut variety trials were planted in Western Sudan in 1983. In Trial I, the highest yielding cultivar out-yielded Barberton by 38% in Dimsu, 121% in Kadugli, 120% in El Fuda and 67% in El Obeid (Table 49). Line ICGS81-20 was the highest yielding line in El Obeid and Kadugli in Trial II. It out-yielded Barberton by 22% and 48% in El Obeid and Kadugli, respectively. In El Fuda ICGS 81-18 had the highest yield, with 1572 kg/ha. Barberton produced 1142 kg/ha (Table 50).

Numerous crosses have been made by the ARC groundnut breeder which include parents with resistance to infection by Aspergillus flavus group fungi (A.flavus infects groundnuts and other crops. It produces aflatoxin which can cause cancer.) (27). Efforts are being made, also, to develop suitable sequential runner type plants, that would spread the pods out in the soil so as to increase their uptake of water and calcium. The objective is to produce a plant that is drought tolerant, but, in years with higher rainfall would increase its productivity by putting out additional runners and pods (28).

Sesame

A sesame variety trial was conducted at Kaba (5 miles South of El Obeid) on Gardud Soils and at the Goz Ashgar Central Forestry Reserve in 1974/75. Yields were higher in Goz Ashgar, perhaps due to the fact that it received 479mm of rainfall while Kaba was estimated to receive only 346mm. None of the introduced lines out-yielded the highest yielding local cultivar. Heraihri ranked first in Kaba and second in Goz Ashgar. Baladi was highest yielding in Goz Ashgar, but, ranked 15th in Kaba (Table 51). A similar trial was conducted in Kaba in 1975/76, when there was only 198mm of rainfall in El Obeid. Baladi ranked first and A-15-18 produced the second highest yield (Table 51).

Cowpeas

WSARP evaluated a cowpea trial in 1983 prepared by the Bean and Cowpea CRSP in Telo (Kadugli) and Kaba (El Obeid). Most of the introduced lines yielded 2 to 4 times more beans than local cultivars. Chino MI from the USA had the highest yield in El Obeid and cultivar 58057 from Senegal was highest yielding in Kadugli. The American line 1-12-3 was the only entry to do well in both Kadugli and El Obeid (Tables 52,53). The leaves of at least one of the local lines stay green after most of the beans have reached maturity, which makes it a better forage crop. WSARP will continue to seek lines that are both high yielding and good for forage.

Nine out of 18 entries in an evaluation trial of IITA cowpea out-yielded the local cultivar in Dimsu in 1983. Lint TUX 3236-01G was the highest yielding. It produced more than twice the weight of beans as the local cowpea (Table 54). However, none of the IITA lines had a color or cooking characteristic comparable to the local cultivar (10).

Other Grain Legumes

Several trials for screening mungbean and soybean cultivars were conducted in Kadugli in 1983. The top 5 yielding mungbean lines produced 70% more beans than the top 5 lines of soybean or cowpea (Table 55). Mungbean is earlier maturing than either soybean or cowpea and, as a result, less affected by the early termination of the rainy season. However, it has yet to be determined whether it is an acceptable food for the local populace.

Fodder Legumes

None of the exotic legumes or grasses planted on the new WSARP Experimental Farm in Kadugli in 1983 emerged. The only genera that grew well were Vigna, Clitoria, and Cajanus, which were indigenous to the area. Similar results were obtained from trials planted in nearby Telo. The only exotic species that germinated was Macroptilium Sp. Poor quality seed was the cause of the poor germination in most cases. Attempts were made to get better quality seed for the 1984 trials and to

conduct germination tests in the laboratory before planting to improve germination percentage.

In 1983, the three forage legumes that grew well and nodulated freely with active nodules produced seed when planted early. Pigeon pea (Cajanus cajan) had good growth, large and active nodules, but appeared too stemmy to make a good feed. Hyacinth bean (Dolichos lablab) and Lab lab purpureus produced abundant forage and usually had large but inactive nodules. They bloom and set seed well after the time for harvest and, therefore, could not serve as a seed source for farmers (4).

The HTS consultant agronomist to the Western Savannah Development Project, in regard to the introduction of fodder legumes in crop rotation schemes in southern Darfur, states:

> "... if it is envisaged that fodder legumes are to be used as an improved fallow break and as a supplemental grazing source then clearly legumes that require annual establishment are not likely to be practical... of far greater significance to the project is the identification of a legume that, once established, will persist for a minimum of 3 years. Such a legume should be freely nodulating, produce significant amounts of organic matter, show reasonable resistance to dry season grazing, fire and be sufficiently vigorous to suppress noxious weeds." (6)

Horticultural Crops

Nine watermelon cultivars were planted on the WSARP Research Farm in El Obeid on 26 July 1983. Although no significant differences in marketable yield were observed, the cultivars Black Diamond and Charleston Grey had the highest marketable yields of 18.5 and 17.5 t/ha, respectively. Significant

differences were found between mean fruit weights. Black Diamond and Charleston Grey had the largest fruits with a weight of 4.6 and 4.4 kg,respectively. Many fruit were attacked by crows which caused fruit to crack and reduced marketable yields.

Irrigated tomato and radish varietal trials were conducted during the dry-season in Banjadeed in the 1983/84 season. The results are included in the On-Farm Trials section of this report.

Conclusions

Millet yields in the decade ending in 1983/84 were 54% and 73% of the respective yields in Kordofan and Darfur Regions for the decade ending in 1970/71. The search for improved, higher yielding millet cultivars which started in the 1974/75 season did not really begin in earnest until INTSORMIL, ICRISAT/ARC and WSARP trials were initiated in Western Sudan in the early 1980's. Cultivar performance has in general been very location specific. However, the newly released cultivar Ugandi and the ICRISAT/ARC Bristled Population did well in the major millet growing areas across Western Sudan in 1984 when rainfall levels were far below normal.

Sorghum yields have decreased in Western Sudan, but, not as rapidly as millet. In the decade ending with the 1983/84 season, sorghum yields were 70% in Darfur and 80% in Kordofan

of the levels achieved in the decade ending in 1970/71. Local cultivars performed well under ideal conditions (i.e. good soils and plentiful rainfall), but, introduced earlier maturing cultivars out-yielded them on marginal soils and under limited rainfall conditions. Cultivars released from an earlier breeding program for the rainlands of Eastern Sudan, especially, T.U.B. 7, Dabar, and Gadem El Hamam do well in Western Sudan. Gadem El Hamam is earlier maturing than Dabar, but, does not have as good a grain quality for flour or asiida. Other crosses from the program that produced these cultivars should be evaluated more fully in northern Kordofan and southern Darfur where more than half of the sorghum produced in Western Sudan is grown.

Northern Kordofan and southern Darfur produce 85% of the groundnuts grown in Western Sudan. Groundnut yields have declined less over the last decade than millet, sesame or sorghum. In Kordofan and Darfur yields, over the decade ending in 1983/84, were 89% and 90% of the levels in the decade ending in 1970/71, respectively. Numerous cultivars have displayed a yield potential greater than Barberton, the most widely planted cultivar in Western Sudan. The ARC is attempting to breed superior cultivars with higher yield potentials and resistance to *Aspergillus flavus* infection. One or more improved cultivar(s) may be released by the ARC in the near future.

Sesame is an important cash crop in Western Sudan, but has received little attention to date; WSARP is cooperating with the ARC's Kenana Research Station in an attempt to select improved cultivars of sesame. In the last decade, sesame yields in Kordofan and Darfur averaged 62% and 75% of the yields achieved by farmers in the decade ending in 1970/71.

The grain legumes, cowpea, and mungbean, show promise for introduction into Western Sudan farming systems. More intensive screening by WSARP is planned to identify lines capable of producing an economic harvest of both beans and forage. Screening of forage legumes has only just begun. Additional trials are needed to find the genera best suited to Western Sudan range and crop land.

The horticultural crop production in Western Sudan is significant. WSARP has initiated a research program to improve productivity beginning in Kordofan. The WSARP program is based on the results of a survey of the Horticultural Resources of Kordofan conducted in 1981. See WSARP Publication No. 6 and No. 27 references (15) and (38) in this paper.

Consumer preference, net economic return, market acceptability, and yield potential when interplanted with other crops on farmers' fields, all must be taken into account in selecting promising cultivars for traditional farms in

Western Sudan. Close collaboration between social and agronomic scientists is needed to provide these data for potentially important cultivars.

Improved seed production, processing/distribution of current cultivars would improve farmers' yields. These are even more important if farmers are to realize the full benefits of genetically superior germplasm. The successful introduction and acceptance of hybrid seeds by traditional farmers is dependent upon a guaranteed supply of hybrid seed, annually, since the seed harvested from hybrid lines is genetically diverse and has an inferior yield potential. Therefore, a dependable seed production and supply system is vital to raising the productivity of farmers in Western Sudan today and in the future. See WSARP Publication No. 16, reference (16) in this paper for a comprehensive review of seed programs and problems in Sudan.

CULTURAL PRACTICES

Introduction

The cultural practices used in producing a crop and the growing environment in large measure determine whether the genetic potential of the planted seed is fully realized. Although atmospheric conditions in a given location cannot be changed, appropriate crop management can raise crop productivity. Some techniques are known that can improve crop establishment, enhance growth micro-environment (soil and atmosphere), increase water-use efficiency, and control damage by plant pests (weeds, diseases and insects) under semi-arid conditions - others must be developed to meet the particular needs of farmers in Western Sudan. Improving the cultural practices of traditional farmers in Western Sudan is more difficult and time consuming than introducing new cultivars, since the environment is harsh and the resources of the farmers are severely limited. It is, however, equally as important as identifying and introducing superior germplasm. Even the best seed with optimal levels of fertilizer applied will not produce a good yielding crop if it is not managed well.

Kadugli is apparently in a better position than other stations in Western Sudan to benefit from ARC research conducted in

East-Central Sudan (Kenana Research Station in Abu Naama) and at ICRISAT (in Hyderabad India), as it has a similar environment and soil type to Abu Naama and Hyderabad. However, an ICRISAT soil scientist reported after visiting Kadugli recently:

> "The agricultural environment at Kadugli is sufficiently different to that at our Hyderabad location that immediate transfer of the present ICRISAT Farming Systems technology for deep vertisols is not possible. The major limitation is the shorter rainfall season, thus apparently preventing double cropping...The lack of a large body of research data for the area such as led to the development of ICRISAT's Technology (10 years of our own research plus a large body of existing results from Indian Institutions), is perhaps the next constraint;...
>
> (An) attempt to adapt ICRISAT's present findings to the present Nuba Mountain situation, by conducting substantial further research...(would require)...a substantial commitment for several years (e.g. 5-7...)" (12).
> (See Item 1 in the Appendix for additional excerpts from this report).

The results of trials presented on the following pages are preliminary, but, they are indicative of the types of modifications which have the potential to increase crop productivity in Western Sudan.

Improvement of Crop Establishment

The INTSORMIL agronomist in El Obeid is evaluating a simple means of producing larger millet and sorghum seeds to improve crop establishment and seedling vigor. Larger seeds provide young seedlings with a greater reserve of plant nutrients on which they can draw until photosynthesis is initiated. As a result, larger seeds can be planted deeper. In a hot, semi-arid environment this may reduce the heat stress on the seed and the chance of germination being triggered by a light shower that provides insufficient water to sustain seedling growth.

The agronomist from INTSORMIL cuts off a portion of sorghum and millet heads at flowering to increase the growth of the remaining seeds. Baladi-White millet seeds were increased in weight by nearly 30% and IS 9830 sorghum seeds were heavier by nearly 22% as a result of cutting off two-thirds of the head at flowering (3). The larger seeds of sorghum and millet planted in a greenhouse trial at a depth of 3cm in sand had an increased 14 day seedling height of 44% and 115%, respectively. The effect of larger seed size was not as great when planted in clay (Table 56).

Farmers throughout Western Sudan have found a positive yield response to treating seed of sorghum, millet, sesame and groundnuts with Aldres-T, Sweda or Dawa suwaid, a combined

insecticide/fungicide (22).* The insecticide reduces root damage caused by termites, ants and, perhaps, other insects in the soil. The fungicide reduces head smut fungus of sorghum. The benefit of the fungicide to other crops is not clear, at present. The widespread acceptance of farmers of the the benefits of this seed dressing led WSARP to include it in their package of recommended practices for sorghum production in southern Kordofan (21). The quantity of Aldres-T available to farmers in Western Sudan is limited so its use as a seed dressing is restricted.

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* Contains 25% Aldrin and 50% Thiram. In the USA, the registration of Aldrin has been cancelled, except for termite control and dipping of non-food roots and tops. An alternate seed dressing of Lindane and Thiram may be preferable (32).

Improvement of Soil and Water Management and Conservation*

Water availability is the most serious limitation to agricultural production in Western Sudan. It is a result of the combined effects of weather and soil conditions. Rainfall is low (normally 386mm for El Obeid and 732mm for Kadugli, for example) and its distribution is poor. In more recent years the annual rainfall has been significantly less than the long-term average indicated above. For example, in the 1984 season in El Obeid the total rainfall from July to September was less than 150mm in most location (33). The rainy season normally extends from June/July to September/October. However, the period between the first and last useful rain is limited to 70 to 90 days only. This limits the choice of crop varieties to short maturing types.

Although the total annual rainfall may seem to be adequate to meet the consumptive use requirement of the semi-arid zone crops such as millet and sorghum, crop failure is frequent. Because of poor distribution of rainfall, moisture stress may develop at the critical stages of growth. Also, much of the rainwater is lost through runoff, evaporation, and weed transpiration. The amount of water available to crop plants is a small fraction of the total rainfall. An efficient use of the available rainfall can be made through management

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practices that maximize soil water storage and minimize wasteful losses, allowing optimum plant growth and development.

Intake of water and its retention are greatly affected by soil physical condition and atmospheric evaporativity. In northern Kordofan sandy soils (Qoz) cover almost 70 percent of the area. Qoz soils have a very poor water and nutrient holding capacity. Rapid drying of the surface zone in Qoz soils appears to be a major cause of seedling failure. Also, these soils are more susceptible to wind erosion.

Gardud soils, the second most extensive soil type in northern Kordofan, are very hard and difficult to cultivate with traditional hand tools. Water infiltration in gardud soils is very low. As a result, much of the rainwater from gardud lands is lost as runoff. The surface of gardud soils is highly eroded and stoney.

Cracking vertisols dominate the lands in southern Kordofan. These are potentially productive soils with high water and nutrient holding capacity. However, because of severe cracking on drying, and surface sealing upon wetting, losses of rainwater through runoff and evaporation are high. The WSARP program for soil and water management and conservation of these soils is summarized in the following paragraphs.

Water Retention and Evaporation Control in Sandy Soils

Although water intake is rapid in sandy soils, they also have a rapid drying rate. Soil amendments can increase water retention and retard drying. Some local materials such as gum arabic and clay soils have been tested by WSARP and seem to be effective in reducing evaporative loss of water from sands. Further research is needed to determine optimum economic rates as well as methods and timing of application.

Mulching

Mulching can control erosion, improve soil structure, increase infiltration, reduce evaporation, and suppress weed growth. Doxiadis Associates used plastic mulches on sandy soils near El Obeid and found them very effective in conserving moisture (34). Mean total yields of eggplants were 2 kg/plant for the mulched plots and 0.1 kg/plant for the control (without mulch). Plastic mulches are impractical for a region like Western Sudan. However, mulches composed of locally available natural materials may prove useful in conserving moisture. WSARP field trials using crop residue as mulch are underway in northern Kordofan and appear to be quite promising. Trials have also been initiated by WSARP in Kadugli.

Planting in Seed Cradles

Seed cradles are shallow holes made at regular intervals into which seeds are planted. Their purpose is to accumulate water and provide a protective environment for seedlings. A form of seed cradle is being used in Darfur on a farm near El Fasher with very good results. WSARP efforts with seed cradles have been unsuccessful in sandy Qoz soils because of the unstable nature of the sand. Within a day or so the seed cradles become filled with sand. On gardud soils, however, seed cradles appear to be very effective. Observations show that seed cradles accumulated water while much of the rain falling on adjacent gardud soils, without seed cradles, was lost as runoff. Eight crops were planted in an observation trial on gardud soil to compare growth and establishment of seedlings with and without seed cradles in 1984. Eighteen days after planting more than 90 per cent of the seed cradles had seedlings with vigorous growth. Most seed not sown in cradles did not germinate and those that did produced seedlings which were pale and stressed.

Ridge-Furrow Cultivation

Furrows capture water and ridges provide protection against wind erosion. It is easy to make ridge-furrow beds on sandy Qoz soils but experience in the 1984 season has shown that furrows in sandy soils fill up and ridges collapse under the action of wind and rain. On gardud soils (northern Kordofan) and vertisols (Nuba Mountains) stable ridges can be made,

but, the effort required is large. Tractors are usually required, as ridges can be made with hand tools only with difficulty. WSARP is looking into ways of maintaining the ridges and furrows for several years so that plowing costs could be spread out over a longer period.

Capturing Runoff

Gardud soils in northern Kordofan are highly compacted and allow very little infiltration. As a result a large amount of rainwater runs off to khors. Surface sealing in vertisols in southern Kordofan produces a similar effect. Contour bunding could be an effective means of capturing runoff and increasing infiltration. The technique could be particularly effective in rehabilitating gardud soils which remain virtually dry all year round. Water stored in the soil will support vegetative growth and initiate structural improvement. The idea of water spreading in Darfur is based on the premise that water needed for crop production can all be stored in the soil profile. It has been quite successful on a farm operated by Dr. Motasin, an El Fasher Physician.

Drip Irrigation for Horticultural Production

Horticultural production in Western Sudan depends on the availability of irrigation water. Critically low supplies of water and wasteful methods of irrigation make it necessary

that efforts be made to educate farmers in new technologies of irrigation. The drip system is the most efficient method of water application, with almost 50 percent reduction in water usage. Pumping costs are reduced accordingly. Labor requirements to maintain open channels is eliminated. Water is delivered directly to individual plants and dissolved fertilizers can be fed to the plants via drip outlets. Spaces between rows are always dry so that weed growth is minimal and farm operations such as staking, picking, and pruning continue uninterrupted. The need for earth-work (leveling) to move water from one end of the field to the other is completely eliminated.

WSARP will be evaluating drip irrigation at the WSARP Horticultural Research Farm in Benno, near El Obeid.

Enhancement of the Growing Environment

The correct date of planting of a rainfed crop is critical. Planting too early may result in premature seed germination before soil moisture is sufficient to sustain a crop. Planting too late reduces the length of the available growing period with adequate rainfall. The best planting date for sorghum cultivars Dabar and Gadem El Hamam in 1979 in Kadugli was early June. The crops planted in the first of June yielded 22% more than those planted in mid-June and 96% more than those planted in the first of July (Figure 2). The

optimal planting date of a given rainfed crop will vary from year to year depending upon when the rains begin. Thus, it is better to describe the optimal planting times in terms of the amount of accumulated rainfall that is needed before planting rather than a given calendar date. Observations in Kadugli over a number of years appear to indicate that sorghum should be sown after the first 50-100mm of rainfall have occurred (21).

Plant population density controls crop production per unit area. The number of plants in a given area must be relatively high for the area to produce a high level of grain. On the other hand, plants growing too close together shade each other and reduce the portion of the soil from which each plant draws its nutrients, and may deplete the soil moisture before plants reach maturity. Optimal plant spacing depends on the shape of a particular cultivar (plant architecture) and soil fertility. The optimal spacing interval may be changed, for example, if fertilizer or water is added to the crop.

The ARC conducted trials in the vicinity of El Obeid at Wad Ashana, Alloba and Umm Damm Hag Ahmed in the 1970/71 season. Many of the trials were designed to measure the effect of plant spacing on final population density and yield. A millet trial at Wad Ashana produced the following results:

> "Variety Kordofani, being an early maturing variety yielded significantly more grain than the late (maturing) Jabali (P=.001). Both varieties yielded significantly more grain under wider spacing as

> compared to the closer one (Table 57). Neither N nor P had any significant effect on grain yield. However, there was a tendency for grain yield under close spacing to be less in the presence of added nitrogen." (29) (N and P were added at the rate of 20kg/ha and 20kg P/ha).

In 1975/76 two millet trials were planted in Kaba with some common entries but different plant spacings. In general, planting in rows 60cm apart gave higher yields than planting with a spacing of 45cm between rows (Table 58).

Sorghum plant population was increased by closer inter-row spacing and increased plants per hole at Alloba in 1970/71 (Table 59). However, grain yield was decreased by both of these treatments (Table 60).

> "It was clear that under conditions of low rainfall, wider plant spacing, single plants per hole and early maturing varieties were more advantageous for crop yield than other tested factors." (29)

The effect of spacing and interaction of variety and spacing on sorghum yield was statistically significant at Wad Ashana in 1970/71 but the effect of number of plants per hole on yield was not significant (Table 61).

> "...tested spacing had no effect on the yield of Wad Akar variety, but, the closer spacing resulted in significantly lower yield in Umm Benein variety." (29).

Wider spacing significantly increased groundnut yield at Wad Ashana in 1970/71 (Table 62). Plants spaced 30cm apart had the following characteristics compared to those spaced 20cm apart: lower number of pods per unit area, higher 1000 seed weight, slightly higher shelling percent and higher pod yield

per unit area. The same was true for a groundnut trial planted in Alloba in 1970/71. Varietal differences in response to spacing of groundnuts were observed in a trial planted in Gubiesh (Geneban), located southwest of El Obeid, in the same season. Barberton and a local cultivar had higher yields under wider spacing, but, the cultivars Natal and Libyan produced more when spaced closer (29).

In a trial planted in Wad Ashana in 1970/71 both early and late maturing cultivars of sesame had higher yields when spaced 30cm apart than with a 20cm spacing (Table 63).

A Kerkadeh spacing and fertility trial was conducted at Alloba in 1970/71. The air dry weight of the stems was increased by the addition of phosphorus fertilizer (1/2 P 22kg P_2O_5/ha) and wider spacing. Only spacing, of the factors tested, increased yields significantly. Fruit yield was higher in plots with wider spacing and no nitrogen (Table 64).

> "This was understandable under conditions of low rainfall where nitrogen fertilizer through its increase in plant size resulted indirectly in quicker soil moisture use, thereby creating soil moisture stress which leads to cessation of growth earlier in plants receiving nitrogen over those which were not." (29)

Plant spacing trials were conducted in El Fuda beginning with the 1980/81 season. Wider spacing of sesame in a 1980/81 season trial decreased the number of plants per hectare but the plants compensated by producing more seeds per plant. As a result, yields were nearly constant (Table 65). A similar

result was found for cowpeas planted in the 1981/82 season (Table 66).

A millet spacing trial in El Fuda in the 1981/82 season produced the following results:

> "Spacing significantly affected plant population but not grain yield. The number of harvested heads increased with narrower spacing but the increase was insignificant. There was a vivid compensating effect: at the lowest population there was a good number of fruiting tillers, at the highest 40% of the plants failed to produce harvestable heads and head weight dropped by some 40% also (Table 67). Either soil moisture or nutrients or both were not adequate to support such a crop." (37)

Groundnuts were sown with two seeds per hill in a 1981/82 season plant spacing trial in El Fuda with the following results:

> "There was a highly significant (P 1%) increase in both pod yield and harvested plants with narrower spacing. Shelling out-turn also significantly (P 5%) increased with narrower hole spacing. Consequently rate of increase in kernel yield was greater than that for pods. Yield per single plant decreased as plant population increased." (37) (Table 68).

Seeding rate trials were conducted in El Fuda with millet and sorghum in the 1980/81 and 1981/82 season with the following results:

> "Both (millet) grain yield and plant population increased progressively with seed rate. Differences in yield were significant (P 0.05). The crop stand was uneven and there was vigorous tillering. Plant number and yield did not increase in proportion to the increase in seed. It seems that the proportion of seeds giving mature plants decreased with increased seed rate. No count of harvested heads was made but apparently many plants failed to develop seed, the proportion of such barren plants increasing with plant population." (37) (Table 69)

> Though (sorghum) grain yield per unit area decreased consistently - and notably - with increasing seed rate, differences were not significant statistically. Plant populations increased significantly (P 5%) with increasing seed rate, but the increase was not proportionate to the increase in seed. Perhaps with higher seed rates there was higher seedling mortality. The number of harvestable heads rose then dropped with the increase in population. At the highest plant population there were clear symptoms of water stress and most plants failed to develop heads (significant at 1% level). This effect was also reflected on yield per head which decreased with increasing seed rate and crop density. (Table 70)
>
> There was a very pronounced unevenness in crop stands in this and other (1981/82) sorghum trials. Some parts of the plots were crowded with vigorously growing plants while other parts were almost barren or with few weakly-developed plants. Therefore, the above results should be considered carefully. It seems that the soil and moisture would have supported the highest plant population recorded to full grain maturity and good yield, if the plants were evenly distributed. But yields suffered from the two extremes of no, or very few, plants at on extreme and over-crowded plants, at the other. The change within a plot from one extreme to the other was usually sudden, reflecting most probably changes in some soil characteristic. It is believed to be a matter of very localized soil crusting which prevent seedling development or water penetration or both. The rooting system of the crop may be a factor as this phenomenon of uneven stand was noticed in sorghum and millet but not in sesame and groundnuts.
>
> If ways are found to overcome this patchiness of stands, yields of sorghum - and pearl millet - can be greatly increased." (37)

Sorghum cultivar P898012 planted without fertilizer or irrigation in Banjadeed in 1983 achieved the highest yield at a population density of 24,000 plants per hectare. Millet cultivar Ugandi showed little yield response to population over the range tested (Table 71). Additional tests of

cultivars of both crops are needed at other locations before any recommendations can be made with regard to optimal population density.

A trial to evaluate intra- and inter-row spacing with rainfed watermelon was planted on the WSARP El Obeid Research Farm on 29 July 1983. Closer intra-row (in-row) spacing increased significantly the number of plants and yield per hectare. Plants spaced 1m apart in a row yielded 8.8t/ha, while those spaced at 2m intervals produced 5.5t/ha. The number of fruit per hectare was increased from 1800 to 3150 by cutting the spacing distance from 2m to 1m. Although the inter-row (between-row) spacing had no significant effect on yield or number of fruits, both were higher for the closer spacing (Table 72).

Labor is the primary input and constraint to traditional crop production in Western Sudan and weeding is the most time-consuming activity (Figures 3 and 4). Weeds compete with crops for soil nutrients and their vigorous growth can sometimes smother a crop, especially when it is young. Therefore, early weeding is important. Weeding interval trials were conducted on sorghum in Kadugli in 1978 and 1979. The results of the 1978 trial clearly demonstrated the benefits of early weeding. Treatments which were weeded 7 days after planting yielded at least 1200 kg/ha while those that were not weeded until 14 days after seeding yielded less

than 700 kg/ha. Weed free plots yielded 1723 kg/ha (Table 73). Improved cultural practices for Kadugli being evaluated in on-farm trials recommend at least one early weeding, based on the above results and other observations. The traditional practice had been to delay initiation of weeding until several weeks after planting and continue it till the end of season.

Plowing and/or application of herbicide to control weeds in millet was evaluated in Nyertete in 1982. Pre-planting plowing reduced weed growth more than herbicide application (Figure 5). The application of the herbicide Gesaprim, without plowing, was the most economically efficient, labor saving method (Table 74). However, there are yield advantages to plowing itself, as was demonstrated in Dimsu and Jebel Marra in 1983 (Tables 75 and 76). Therefore, the best overall single treatment may be plowing, alone, as is explained in the following quote from a Jebel Marra Rural Development Project Report:

> "These calculations (Table 74) all assume an equal and optimal level of weeding (labor plus control method) and if other indications are correct ploughing also would have resulted, at Nyertete, in a yield advantage unrelated to weed control of up to 222 kg/ha valued at about LS 88.8. If this was the case, then clearly the best option is ploughing alone, yielding a net benefit of LS 104.3 ha. If ploughing is not used, the best option is a cheap herbicide, but this is less feasible owing to technical problems. Use of herbicide together with ploughing is not worthwhile. The final indications relate to the cost of ploughing or herbicide compared to labor in terms of weed control effectiveness.Ploughing, costing LS 45.0/ha, saves LS 60.5 worth of labor and therefore represents a cheaper weeding method. Used in combination with existing labor, it lowers the average cost of

> weeding (whether measured in direct or "opportunity cost" terms) and therefore should encourage farmers to aim for a more perfect level of weed control and higher yields per unit area. A cheap herbicide such as Gesaprim could have the same effect." (9)

A comparison of the millet yield in Nyertete and the mid-season weed density gives an idea of the yield reduction caused by weeds (Figure 6). Control of Nafassa, a millet head worm, and early weeding produced the highest benefit to cost ratio of several cultural practices, including the addition of nitrogen and plowing, in Nyertete in 1983 (Table 77).

Doxiadis Associates reported in 1965 that sorghum and groundnut planted on ridges, near El Obeid, yielded about 70% more than controls planted on flat ground (7).

Intercropping one crop with another may increase the yield of one or both of the crops due to synergetic effects such as controlling weeds, reduced soil erosion, increased organic matter, or complementary nitrogen fixation. Groundnut yields were increased by intercropping with millet or sesame in trials near El Obeid in 1983. Soil erosion was reduced in the plots in which groundnuts were intercropped with millet, and millet yields were higher than when planted solely (Table 78). In other 1983 trials, intercropping of sorghum and millet, as well as sorghum or millet with cowpeas, showed promise in the El Obeid area (3).

The rotation of crops planted on a given field can increase yields of individual crops, and if the sequence includes a legume or legumes, also maintain soil fertility. Doxiadis Associates concluded on the basis of 3 years data gathered in the El Obeid area, 1963-1965:

a. The best sequence for sorghum is sesame-sorghum or groundnuts-sorghum.

b. Good yields are usually to be expected from sorghum crop grown on a land which was under fallow for a number of years.

c. The sequence sorghum-sorghum is to be avoided.

d. The best sequence for groundnuts is sesame-groundnuts or fallow (bare or weeded)-groundnuts.

In order to give precise recommendations about the proper sequence that the local farmers should use to improve the existing pattern of cultivation, it is necessary that the trials be repeated and continued for a number of years, so that sufficient data be available. An attempt, however, is made now to present a model crop sequence system that could be applied by the local farmers and which is based on the above mentioned results. Apart from these results, factors such as root formation and penetration, water and nutrient requirements of different crops were taken into consideration before designing this crop sequence system." (8)

The recommended crop sequence by Doxiadis Associates is: sorghum or millet - legume - sesame - groundnuts - fallow. The sequence may be started with any of the crops with the fallow period following the fourth year of cultivation (8).

In southern Kordofan the GTZ has been working with the Nuba Mountains Agricultural Production Corporation to improve crop production on the privately-owned, mechanized schemes. They found that cotton following sesame yielded three times as much

as cotton after fallow (Table 79). The yield of sorghum in rotations, including one or more legumes, was higher than a rotation without a legume. The best rotation for sorghum production was the sequence: cotton - cowpea - sorghum (Table 80). The rotation resulting in the lowest yields were: sorghum - cotton - sorghum and fallow - sorghum - sorghum (Table 81).

Conclusions:

In southern Kordofan, application of combined fungicide/insecticide to seed prior to planting, prompt planting following the accumulation of the first 50-100mm of rain, and weeding one week after seedlings emerge, appear to be the best cultural practices known at this time for producing a good crop of rainfed sorghum on the cracking clays. Additional research is needed to develop a similar set of suggested cultural practices for northern Kordofan and Darfur.

In the 1984 season WSARP began to give attention to means of improving water management and increasing the utilization efficiency on farmers' fields. Preliminary results indicate promise for mulch to conserve soil moisture on Qoz and cracking clay soils. Seed cradles on gardud soils improved crop establishment in 1984. Simple water spreading methods

being tried in Darfur appear to be an effective means of increasing crop productivity along the khors.

The preliminary trials on increasing seed size to improve establishment of sorghum and millet on sandy soils appear promising; however, additional trials are needed before it can become a recommended practice. In general, wider spacing increased yield of millet, sorghum, groundnuts, sesame and kerkadeh on Qoz soils of northern Kordofan. Millet and kerkadeh yields were lowest on plots with narrowly spaced rows to which nitrogen was applied. This stimulated early growth causing the plants to deplete available soil moisture prematurely. Millet yields were unaffected by spacing in a trial planted at El Fuda in southern Kordofan, but the number of heads per unit area increased with closer spacing. On the other hand, higher seed rates increased both the plant population and yield of millet. Sorghum plant population in El Fuda was increased by narrower spacing and more plants per hill, but yield was decreased. However, narrowly spaced groundnuts in El Fuda had the highest yields. An in-row spacing of 1m between plants produced a higher watermelon yield in El Obeid than 2m spacing.

Plowing as a means of improving crop production and controlling weeds is dependent upon the availability of traction and the net economic gain in a particular location.

The identification of appropriate intercropping combinations and crop rotation sequences are being given high priority by WSARP in Kadugli and El Obeid. Results should soon be forthcoming.

Steps should be taken to increase the availability of appropriate seed dressing for traditional farmers in Western Sudan.

ON-FARM TRIALS

Introduction

There is a growing recognition of the importance of trials on farmers' fields as a supplement to on-station trials in developing appropriate technology for farmers. On-farm trials are needed to evaluate the suitability of a given technology - agronomically and economically under conditions representative of target farmers in each recommendation domain. On-station trials are needed to select, develop and/or understand new technologies that may ameliorate one or more constraints to crop production. On-station and on-farm trials are both essential to finding solutions to the production problems of traditional farmers in Western Sudan.

The results from only a few on-farm trials are available at this time; more will be forthcoming soon. The results of several trials are included to illustrate what can be learned from on-farm trials.

Jebel Marra

Sorghum cultivars that were developed in East-Central Sudan were grown on a number of farmers' fields in the Jebel Marra region in 1982. The farmers' line(s) of sorghum out-yielded the introduced cultivars by 16% to 82% (Table 82).

Kadugli

Nine on-farm trials were planned for the 1983 cropping season near Kadugli, three in each of three villages. It was intended to test three treatments on each farm; namely, local cultivar with traditional cultural practices, local cultivar with improved cultural practices and introduced cultivar with improved cultural practices. Gadem El Hamam was chosen as the introduced cultivar. The improved practices were: application of seed dressing, higher planting population density and good weeding practices.

Two transhumant cooperators thought they had left their trials in good hands when they migrated to the North with their herds, but, they did not. These trials were so poorly tended that they had to be abandoned. Another cooperator became ill after planting his trial and was unable to hire laborers to weed it. Therefore, it, too, had to be abandoned. Three of the six remaining cooperators failed to adequately carry out one or two of the three treatments. Thus, only 3 farmers planted all the trials as planned. The introduction of improved cultural practices with the local cultivar(s) produced erratic results. However, the application of improved practices on an introduced cultivar was superior to both the other treatments (Table 83).

El Obeid

Eleven on-farm trials were conducted in the El Obeid region in 1983 by the INTSORMIL agronomist. In mid-August, nine of the eleven sorghum and millet crops were ranked as good to excellent. However, by the end of the season only one farm had good looking crops; most were rated very poor. Ten of the eleven farmers listed drought as a major production constraint (Table 84). Perhaps improved water management techniques being tested by WSARP might have been able to save some of these crops.

Six on-farm trials were conducted in Banjadeed by the WSARP horticulturist in the 1983-84 dry season. Plants were grown on ridges rather than on flat beds, as is the usual practice by local horticultural growers. The farmers observed how much easier and more efficient it was to irrigate the furrows and ridges. Neighbors of the farmers where the trials were conducted began to try planting on ridges. They noted that they could irrigate a crop faster thereby saving not only their own time, but diesel fuel for the pumps. Specific results of the experiments are given in the following paragraphs.

Eight tomato cultivars were seeded 26 September and transplanted into the field 20 November. There was no significant difference in yield between the cultivars evaluated. The average yield of all the entries was 19t/ha.

Chico 111 was earliest to mature (106 days to flowering) and had the smallest fruit size (36).

Six radish cultivars were direct sown in the field on 5 January 1984. There were no significant differences in yield between the entries. The average yield was 12.5t/ha. China Rose Winter had significantly larger root weight. White Icicle was more acceptable in the market due to its white color. It, also, had the highest yield (ns) (36).

Four cultivars of onion from Hudeiba Research Station were planted in the field on 3 December. Five levels of nitrogen (urea), ranging from zero to 160 kg N/ha were applied in a randomized complete block design. There were no significant differences in yield or bulb size between the cultivars or fertilizer treatments (36).

Sweet peppers were sown on 5 October 1983 and transplanted into the field 1 December in a nitrogen and spacing trial. Three in-row spacings (30cm, 45cm and 60cm) and five nitrogen levels (0, 40, 80, 120 and 160 kg N/ha) were evaluated. Plants with the closest spacing (30cm) had significantly greater yield than plants with widest spacing (60cm) (Table 85). Although the response to N was not significant, the control (no nitrogen) gave the lowest yield. No marked differences in fruit weight were observed. Similar trials were conducted with eggplant and hot peppers, but neither

spacing nor nitrogen produced any significant differences (36).

Conclusions

Evaluation of fertilizers, cultivars and cultural practices should be done under farmers' field conditions and taken to representative farms at the earliest possible date. Trials should always contain, as a check, the local practices and/or cultivars used by the area's farmers. Improved cultivars and management methods are not better, from the farmers viewpoint, until they prove to be superior to those presently used by the farmers. None of the introduced sorghum cultivars, for instance, out-yielded the farmers' line(s) in Jebel Marra in 1982.

On-farm trials, particularly farmer-managed trials, require more resources to supervise them and even then may fail to give the desired results, as was the case in Kadugli in 1983. However, even failures can give insights into the producers priorities and decision-making processes.

The drought caused failures of INTSORMIL on-farm trials near El Obeid in 1983 showed the importance of incorporating water conservation into the package of improved technologies being evaluated to improve crop productivity in northern Kordofan.

The WSARP on-farm horticultural trials begun in Banjadeed during the 1983/84 season have already induced some farmers to adopt the ridge and furrow method of planting and irrigating, as it enables them to save on pumping costs and labor.

IMPLEMENTS

There are a few new implements being tested in Western Sudan that show promise.

Camel-drawn plows are being manufactured by local artisans for sale to farmers in the Jebel Marra area. The Jebel Marra Rural Development Project has worked with the Agricultural Bank in providing loans to farmers to purchase camels and plows and the arrangement seems to be popular with the farmers in the area. Farmers use the plows to expand their plots and generally get higher yields.

WSARP in Kadugli is cooperating with Urwick Lugg and Gould-Halcrow, who are continuing animal traction studies initiated by SATEC, in evaluating oxen-drawn seeders and carts. Preliminary observations are that oxen may save considerable human labor.

The INTSORMIL Agronomist designed a fertilizer applicator that can be made locally. It appears that it may be extremely useful in assuring the proper placement of fertilizer.

IMPLICATIONS FOR FUTURE RESEARCH AND DEVELOPMENT IN WESTERN SUDAN (WHAT DO WE KNOW AND WHERE DO WE GO FROM HERE?)

GREATER QUANTITIES OF HIGHER QUALITY SEED

The single most important step that could be taken to increase the productivity of farmers in Western Sudan would be to introduce a dependable seed production and supply system. Production, processing and distribution of higher quality seeds of current cultivars would improve farmers' yields. Farmers would reap even higher benefits if genetically superior seeds were made available to them. Varieties from which farmers can save seed from one season to plant the next season's crop are preferable for traditional farms in Western Sudan. Hybrids require use of new seeds each season, and the infrastructure to deliver them to traditional farmers is not present in Western Sudan, nor will it be in the foreseeable future. Introduction of hybrid sorghum in Western Sudan, therefore, should be limited, for the time being, to mechanized schemes which can provide their own annual supply of hybrid seed.

SUPERIOR CULTIVARS FOR FARMERS

Local cultivars of most crops do well in years with average or above average rainfall and are generally preferred by consumers. Earlier maturing genotypes require less water;

therefore, they produce more grain than local cultivars in low rainfall years.

Sorghum

Dabar and Gadem El Hamam, varieties bred by the ARC for the rainfed clay plains in East-Central Sudan, out-yield farmers' cultivars in the Nuba Mountains (on similar cracking clay soils) and in southern Darfur, during years with below average rainfall. Indigenous, medium to late maturing cultivars out-yield introduced earlier maturing genotypes on alluvial soils in southern Darfur, but, Gadem El Hamam and Dabar do better than indigenous cultivars on marginal soils. Dabar has a superior grain quality to Gadem El Hamam for flour and asiida. Additional crosses made in the same breeding program that produced Gadem El Hamam and Dabar have demonstrated a high yield potential in trials in Western Sudan and should be evaluated more fully for grain quality and yield potential. An advanced or elite line, T.U.B. No. 7, appears particularly promising.

In Kordofan, IS 9830 demonstrated a high yield potential and a low striga infestation rate. Hageen Dura #1, the newly released sorghum hybrid yielded well in on-farm trials near El Obeid and Kadugli in 1984. All other entries failed to produce any grain. It should be noted, that tests at the University of Khartoum and ARC's Gezira Research Station have shown Hageen Dura #1 to be highly susceptible to striga.

Millet

Ugandi was the only entry in on-farm trials, in the El Obeid area, which produced heads during the severe 1984 drought. However, the ICRISAT/ARC Bristled Population, also, yielded well on the WSARP Experimental Farm in El Obeid. Previously, Ugandi performed only marginally better in Kordofan than the locally popular cultivar, Kordofani. Neither Kordofani nor Ugandi have done well in Darfur compared to the indigenous cultivars.

Groundnuts

Several groundnut lines in the ARC breeding program have consistently out-yielded Barberton, the most widely planted cultivar in Western Sudan. One of these lines maybe released in the near future, but without improved facilities and infrastructure for multiplication and distribution it may be 5 to 10 years before Western Sudan farmers will benefit from the genetically superior, higher yielding line.

ARC breeders are attempting to incorporate resistance to the fungus, *Aspergillus flavus* into groundnut lines. Groundnuts infected with the fungus produce aflatoxin, a carcinogen. Groundnuts with high levels of aflatoxin are hazardous to consumers' health and cannot be sold in international markets.

Sesame

Sesame is an important cash and oil seed crop in Western Sudan. It has received little research attention in Western Sudan to date. However, WSARP is cooperating with ARC's Kenana Research Station, in East-Central Sudan, to select improved cultivars for farmers.

Grain Legumes

Cowpea and mungbean show promise for introduction into Western Sudan farming systems. WSARP is carrying out an intensive screening program to identify lines capable of producing an economic harvest of both beans and forage when intercropped with cereal or oil seed crops.

Horticultural Crops

A significant amount of fruit and vegetable crops are produced in Western Sudan. Production could be increased by the introduction of improved varieties and cultural practices. WSARP has initiated a horticultural research program in Kordofan aimed at identifying superior genotypes and increasing the productivity of horticultural growers.

INTRODUCTION OF FERTILIZERS ON RAINFED FARMS

There is considerable evidence that cereals, legumes and forage crops respond positively to the addition of phosphorus or nitrogen plus phosphorus fertilizer in Western Sudan when rainfall is adequate. Economic returns to the application of

phosphorus as Triple Super Phosphate, to sorghum and millet appear promising in southern Darfur and presumably will be so elsewhere in Western Sudan, with the possible exception of northern Darfur where rainfall is low and highly erratic. TSP applied at a rate equivalent to 18-20 kg/ha of P_2O_5 increased cereal grain yields and gave benefit to cost ratios ranging from 4:1 to 10:1. Application at a rate of 50 kg/ha resulted in lower benefit to cost ratios.

The response to nitrogen, applied as urea, had not been as impressive or consistent as phosphorus. This may be due to poor placement (on the surface) of urea, which is highly susceptible to loss via volatilization. For example, the yield response of millet to nitrogen in Nyertete, Darfur increased from 5% to 50% when the field was cultivated prior to planting and urea application.

IMPROVED CULTURAL PRACTICES

Large, dense seeds produce more vigorous seedlings, increase stand establishment and, since they can be planted deeper, are less likely to be germinated by light showers that occur prior to the onset of the true rainy season. One method of producing larger and heavier or denser seeds, being evaluated by the INTSORMIL agronomist, is to cut off a portion of the sorghum or millet seed head at flowering.

Crop stand and yields can be improved, also, by treating the seed before planting with a combined insecticide/fungicide. The compound generally used in Western Sudan, Aldrex-T, contains a mixture of Aldrin and Thiram. Aldrin registration in the USA has been cancelled for food crops; thus it may be preferable to introduce a new seed treatment compound in Sudan, such as a combination of Lindane and Thiram.

WSARP is conducting trials to determine the optimum spacing of crops for a given soil type and rainfall regime. In general, the ideal spacing between plants and rows is greater for rainfed than irrigated crops. Plants need to be sufficiently far apart to enable them to extract adequate water and mineral nutrients from the soil without interfering with neighboring plants, but not so far apart that yield per unit area is reduced.

The introduction of legumes into Western Sudan cropping systems is considered a desirable way of maintaining soil fertility, thus reducing or eliminating fallow periods and stabilizing crop production. Intercropping legumes with cereal and oil seed crops appears to be the most promising approach. Ideally, the legumes should be multipurpose and produce grain as well as fodder. Cowpea and mungbean appear to be the best suited for this purpose in southern Kordofan.

Labor is a major constraint to traditional crop production in Western Sudan and weeding requires more labor than any other task. The Jebel Marra Rural Development Project, (JMRDP), found that mouldboard plowing of millet gave higher yields and excellent weed control. Plowing reduced weed mass at time of first weeding in one trial by 80%. JMRDP, also, found that if a farmer cannot weed his entire crop, it is better for him to concentrate weeding efforts on the better parts of a field.

Millet head worm is a serious yield reducing pest. JMRDP found that cypermethrin provided economic, effective control.

Camel drawn plows have proved to be very popular in southern Darfur. Farmers who plow achieve higher yields and are able to cultivate larger areas. Farmers have expressed an interest in having implements for donkeys developed. Ox-drawn carts and weeders, being evaluated in southern Kordofan, are well received by farmers.

The fertilizer applicator, designed by the INTSORMIL agronomist for the placement of fertilizer, may become an essential hand-tool for traditional farmers when chemical fertilizers become readily available.

WSARP has learned that the best means of producing a high yielding sorghum crop on the cracking clays in the Nuba Mountains is to treat seeds with a combined

fungicide/insecticide before planting; plant early maturing varieties, promptly after the accumulation of the first 50 to 100 mm of rain; and weed one week after seedling emergence. Moderate levels of nitrogen and phosphorus have increased yields, but, have not yet been economically evaluated in southern Kordofan.

Limited and highly variable rainfall is the most serious physical constraint to increasing agricultural productivity in Western Sudan. Therefore, WSARP is focusing research on how to utilize available rainfall more efficiently. Preliminary results show that more than 90% of seeds planted on Gardud (clayey pediplain) soils in seed cradles (shallow soil depressions made with hand-tools) germinated and produced vigorous seedlings. Most seeds planted in the traditional manner did not even germinate. JMRDP finds that tied ridges retain rainfall and provide an even distribution of moisture throughout the growing season. Tied ridges were superior in retaining runoff to open ridges and plowing.

EXPANSION OF ON-FARM TRIALS

More trials need to be conducted on farmers' fields to assure that new varieties and cultural practices are truly improvements. WSARP on-farm trials have introduced improved irrigation and planting methods to vegetable growers in Banjadeed. Farmers immediately recognized the saving of

water, time and diesel fuel for pumping and began to try the new techniques on their own plots.

Research administrators should realize that on-farm trials, though beneficial (and perhaps essential to the modernization of agriculture) in Western Sudan, require more resources, i.e., technicians, vehicles, fuel, communications etc. to supervise them.

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TABLE 1

AVERAGE ANNUAL CROP PRODUCTION IN WESTERN SUDAN 1975/76 - 1979/80
(TRADITIONAL PRODUCTION EXCEPT AS NOTED IN FOOTNOTES)

CROP	KORDOFAN			DARFUR			WESTERN SUDAN	NATIONAL
	NORTH	SOUTH	TOTAL	NORTH	SOUTH	TOTAL	TOTAL	TOTAL
	(000) mt.							
SORGHUM	114	173 [1	287	9	107 [4	116	403 (329) [5	1977
MILLET	153	11	164	82	114	226	390	438
GROUNDNUTS	161	34	195	28	189	217	412	844
SESAME	67	12 [2	79	1	28	29	108 (106) [5	243
MAIZE	0	2.4	2.4	0	0	0	2.4	45
COTTON	0	13 [3	13	0	0	0	13	18 [6
GUM ARABIC	--	--	18	--	--	7	25	33

[1 41.9% FROM MECHANIZED SCHEMES

[2 15.7% FROM MECHANIZED SCHEMES

[3 NEARLY ALL FROM NUBA MTS. MECHANIZED SCHEME

[4 1.7% FROM MECHANIZED SCHEMES

[5 TOTAL: TRADITIONAL PRODUCTION ONLY

[6 AMERICAN TYPE ONLY. TOTAL COTTON PRODUCED IN SUDAN EQUALS 413,000 mt.

SOURCE: DEPT. OF STATISTICS AND AGRICULTURAL ECONOMICS
MINISTRY OF AGRICULTURE AND IRRIGATION

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TABLE 2

AVERAGE ANNUAL CROP PRODUCTION IN WESTERN SUDAN 1975/76 - 1979/80
(EXPRESSED AS A PERCENTAGE OF NATIONAL PRODUCTION)

CROP	KORDOFAN			DARFUR			TOTAL PRODUCTION WESTERN SUDAN	TRADITIONAL	NATIONAL
	NORTH	SOUTH	TOTAL	NORTH	SOUTH	TOTAL	ALL	PRODUCERS	TOTAL
	%								
SORGHUM	5.8	8.7	14.5	0.5	5.4	5.9	20.4	16.6	100.0
MILLET	34.9	2.5	37.4	18.7	32.9	51.6	89.0	89.0	100.0
GROUNDNUTS	19.1	4.0	23.1	3.3	22.4	25.7	48.8	48.8	100.0
SESAME	27.6	4.9	32.5	0.4	11.5	11.9	44.4	43.6	100.0
MAIZE	0	5.3	5.3	0	0	0	5.3	5.3	100.0
COTTON	0	71.1(3.1)*	71.1(3.1)*	0	0	0	71.1(3.1)*	0	100.0
GUM ARABIC	-	-	55.2	-	-	21.4	75.8	75.8	100.0

* NUMBER WITHOUT BRACKETS EQUALS PERCENTAGE OF TOTAL NATIONAL PRODUCTION OF AMERICAN COTTON ONLY.

() EQUALS PERCENT OF TOTAL NATIONAL PRODUCTION OF ALL COTTON.

SOURCE: DEPARTMENT OF STATISTICS AND AGRICULTURAL ECONOMICS
MINISTRY OF AGRICULTURE AND IRRIGATION.

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TABLE 3

TOP ELEVEN (BY VALUE) AGRICULTURAL COMMODITIES
EXPORTED FROM SUDAN
1982

RANK BY VALUE	COMMODITY	UNIT	QUANTITY	VALUE LS.000's
1	COTTON	BALES	450,064	121,130
2	SORGHUM	M.T.	412,768	107,474
3	SHEEP AND LAMBS	HEADS	560,412	59,053
4	GROUNDNUTS	M.T.	179,641	53,554*
5	SESAME	M.T.	76,373	42,864*
6	GUM ARABIC	M.T.	27,595	38,279
7	WATERMELON SEEDS	M.T.	42,210	13,678
8	HIDES AND SKINS	M.T.	5,734	8,913
9	HARRICOT BEANS	M.T.	3,815	3,035
10	KERKADEH	M.T.	2,973	2,658
11	MILLET	M.T.	7,392	2,495
			SUB TOTAL	453,133 (93.8%)
			OTHER COMMODITIES	29,968 (6.2%)
			TOTAL	483,101 (100%)

* INCLUDES SEEDS, CAKE. OIL AND MEAL

SOURCE: APPENDIX III SUDAN FOREIGN TRADE EXPORTS BY COMMODITY
23RD. ANNUAL REPORT, BANK OF SUDAN - MARCH 1983

JJR 11 APR. 84

TABLE 4

RESPONSE TO NPK FERTILIZER

OF MILLET

YIELD & BENEFIT TO COST RATIO

EL FUDA

1981/82, 1982/83, 1983/84

FERTILIZER APPLIED	1981/82 YIELD	1981/82 BENEFIT/COST	1982/83 YIELD	1982/83 BENEFIT/COST	1983/84 YIELD	1983/84 BENEFIT/COST
	kg/ha		kg/ha		kg/ha	
0	426	---	1076	---	1495	---
IN* (½N)	545	2.0	1066	-0.2	859	-14.8
1P (1P)	978	8.3	1778	5.7	1676	2.1
1N:1P (½N:1P)	1195	6.1	1632	3.0	1823	2.6
1P:1K (1P:½K)	945	4.8	1828	4.2	1616	1.0
1N:1P:1K (½N:1P:½K)	1207	4.4	2235	8.0	1690	1.2

CULTIVAR: UGANDI

* TREATMENT W/O BRACKET APPLIED IN 1981/82

TREATMENT W/BRACKET APPLIED IN 1982/83 AND 1983/84

	1981/82	1982/83	1983/84
ESTIMATED COST OF ALL FERTILIZERS (LS/kg) (INCLUDES PRICE, TRANSPORT AND APPLICATION)	0.200	0.400	0.540
COST OF MILLET (LS/95kg SACK)	30	30	57
(LS/kg)	0.316	0.316	0.600
RAINFALL (mm)	634	490	400

SOURCE: ANNUAL REPORTS ON ADAPTIVE AGRONOMIC RESEARCH TRIALS CONDUCTED AT AGADI, SAMSAM AND EL FUDA BY SENIOR AGRONOMIST AND MFG. STAFF. (Prepared by M.A. Mahmoud, Senior Agronomist) 1981/82, 1982/83, and 1983/84)

TABLE 5

GROUNDNUT RESPONSE TO NPK FERTILIZER

EL FUDA

1981/82, 1982/83, 1983/84

FERTILIZER LEVEL APPLIED	1981/82 YIELD	1981/82 BENEFIT COST	1982/83 YIELD	1982/83 BENEFIT COST	1983/84 YIELD	1983/84 BENEFIT COST
	kg/ha	-	kg/ha	-	kg/ha	-
0	721	-	1564	-	1290	-
1N* (½N)	833	2.2	1861	5.2	1216	-1.2
1P (½P)	747	0.2	1909	6.0	1540	4.2
1N:1P (½N:½P)	697	-0.1	2040	4.1	1975	-0.2
1N:1P:½K) (½N:1P:½K)	864	0.7	1947	2.3	1592	1.8

* TREATMENTS W/O BRACKETS APPLIED IN 1981/82
TREATMENT WITH BRACKETS APPLIED IN 1982/83,1983/84
CULTIVAR: BARBERTON

		1981/82	1982/83	1983/84
COST OF FERTILIZER	(LS/kg)	0.200	0.400	0.540
COST OF GROUNDNUTS	(LS/kg)	0.187	0.330	0.433
	(LS/KANTAR)	8.500	15.000	19.7
RAINFALL	(mm)	634	490	449

1 KANTAR = 45.5kg.

SOURCE: ANNUAL REPORTS ON ADAPTIVE AGRONOMIC RESEARCH TRIALS CONDUCTED AT AGADI, SAMSAM AND EL FUDA BY SENIOR AGRONOMIST AND MFC STAFF. (Prepared by M.A.Mahmoud) MECHANIZED FARMING CORPORATION.

TABLE 6

CROP RESPONSE TO FERTILIZER

SESAME / NPK

EL FUDA, 1981/82, 1982/83 and 1983/84

FERTILIZER LEVEL APPLIED	1981/82 YIELD	1981/82 BENEFIT COST	1982/83 YIELD	1982/83 BENEFIT COST	1983/84 YIELD	1983/84 BENEFIT COST
	kg/ha	-	kg/ha	-	kg/ha	-
0	159	-	357	-	412	-
1N (1N)	221	1.3	352	-.1	378	-0.6
1P* (½P)	169	0.2	455	3.4	452	1.4
1N:1P (1N:½P)	321	1.6	495	1.59	488	0.9
1N:1P:1K (½N:1P:½K)	414	1.8	281	-0.68	198	-1.9

*TREATMENTS W/O BRACKETS WERE APPLIED IN 1981/82

TREATMENT WITH BRACKETS WERE APPLIED IN 1982/83 and 1983/84

CULTIVAR: ZIRAA I

		1981/82	1982/83	1983/84
COST OF ALL FERTILIZERS	(LS/kg)	0.200	0.400	0.540
COST OF SESAME	(LS/kg)	0.396	0.659	0.889
	(LS/KANTAR)	18	30	
RAINFALL	(mm)	634	490	449

1 KANTAR = 45.5Kg

SOURCE: ANNUAL REPORTS ON ADAPTIVE AGRONOMIC RESEARCH TRIALS CONDUCTED AT AGADI, SAMSAM AND EL DUDA BY SENIOR AGRONOMIST AND MFC STAFF. (Prepared by M.A.Mahmoud, Senior Agronomist) Mechanized Farming Corporation, 1981/82, 1982/83, 1983/84.

TABLE 7

SORGHUM RESPONSE TO NPK FERTILIZER

EL FUDA

1982/83 & 1983/84

FERTILIZER LEVEL APPLIED	1982/83 YIELD	1982/83 BENEFIT COST	1983/84 YIELD	1983/84 BENEFIT COST
	kg/ha	-	kg/ha	-
0	262	-	478	-
½N	369	1.4	638	2.8
1P	502	1.5	733	2.2
½N:1P	554	1.2	997	3.0
1P:¼K	483	1.1	883	2.9
½N:1P:¼K	631	1.4	978	2.5

CULTIVAR: GADAM EL HAMAM 47

	1982/83	1983/84
COST OF FERTILIZER (LS/kg)	0.400	0.540
COST OF SORGHUM (LS/kg)	0.242	0.450
(LS/SACK of 91kg)	22	41
RAINFALL (mm)	490	449

SOURCE: ANNUAL REPORTS ON ADAPTIVE AGRONOMIC RESEARCH TRIALS CONDUCTED BY SENIOR AGRONOMIST AND MFC STAFF (Prepared by M.A.Mahmoud) Mechanized Farming Corporation 1982/83, 1983/84.

TABLE 8

CROP RESPONSE TO FERTILIZER

SORGHUM

NITROGEN

KADUGLI 1978/79

NITROGEN LEVEL	YIELD
kg N/ha	kg/ha
0	2645
95	2843
190	2924
286	2872

1978 RAINFALL KADUGLI = 742 mm

SOURCE: KADUGLI STATION RECORDS

TABLE 9

SORGHUM RESPONSE TO NITROGEN FERTILIZER

EL AFEIN (KADUGLI)

1983

RATE	YIELD
Kg N/ha	kg/ha
0	990
40	1110
80	1470 **
120	1270 *

** SIGNIFICANT AT 1 % LEVEL

* SIGNIFICANT AT 10% LEVEL

JUNE - SEPT. RAINFALL = 448 mm

SOURCE: GTZ REPORT 1984
INVESTIGATIONS ON IMPROVEMENT OF PLANT PRODUCTION ON VERTISOL SOILS IN THE NUBA MOUNTAINS REGION.

TABLE 10

CROP RESPONSE TO FERTILIZER
SESAME / NITROGEN
EL AFEIN (KADUGLI)
1983

NITROGEN RATE	YIELD
Kg N/ha[1	kg/ha
0	510
40	500
80	440
120	710 **

** SIGNIFICANT AT 1% LEVEL
[1 APPLIED TO PREVIOUS CROP (COTTON?)
JUNE - SEPT. RAINFALL = 448 mm
SOURCE: GTZ REPORT 1984

TABLE 11

SORGHUM RESPONSE TO NITROGEN & PHOSPHORUS FERTILIZER

TELO (KADUGLI)

1983

NPK RATE	YIELD GRAIN	YIELD STOVER
Kg/ha	- - - - - - - - - -kg/ha- - - - - - - - - -	
0-0-0	549	8,230
0-20-0	1105	8,528
20-20-0	1260	9,768
40-40-0	1414	10,115

CULTIVAR: GADEM EL HAMAM

SELECTED TREATMENTS SHOWN TOTAL NO. OF TREATMENTS = 16

JULY - OCTOBER RAINFALL TELO = 345 mm

SOURCE: 1983 AGRONOMY REPORT WSARP - KADUGLI STATION

TABLE 12

CROP RESPONSE TO FERTILIZER
SORGHUM
NITROGEN & PHOSPHORUS
TELO (KADUGLI) 1983

NPK RATE	AVE. YIELD 5 INTRODUCED VARIETIES	LOCAL LINE
kg/ha	- - - - - - - - - - - kg/ha	- - - - - - - - - - - -
40-40-0	976	0
0-0-0	484	0

JULY - OCTOBER TELO RAINFALL = 345 mm

SOURCE: 1983 AGRONOMY REPORT WSARP
KADUGLI STATION

TABLE 13

BENEFIT OF FERTILIZER USE

TRIAL CODE NUMBER	NUTRIENTS USED kg/ha		COST OF FERTILIZER APPLIED PER ha P.T.*	PRICE OF YIELD PER HECTARE P.I. *			PROFIT PER HECTARE (g-d) P.T.	PERCENT OF GROSS INCOME AFTER DEDUCTION OF FERTILIZER COST (h/eX100)
	N_2	P_2O_5		CONTROL PLOT	FERTILIZED PLOT	DIFFERENCE		
A	B	C	D	E	F	G	H	I
SORGHUM								
FT-1/1A/63	40	80	1180	2262	4414	2152	+ 972	+43.0
FT-1/1B/63	40	80	1180	982	2676	1694	+ 514	+52.3
FT-1/1B/63	20	40	590	982	2252	1270	+ 680	+69.2
FT-1/2B/63	40	80	1180	453	1715	1262	+ 82	+18.1
FT-1/2B/63	40	40	860	453	1650	1197	+ 337	+74.3
FT-2/3A/64 (UMM BENEIN II)	30	30	645	6234	9700	2466	+1821	+29.2
FT-2/3A/64 (WAD TABIS)	30	30	645	3134	6600	3466	+2821	+90.0
FT-2/3B/64	30	30	645	676	1384	708	+ 63	+ 9.3
SESAME								
FT-2/4A/64	30	30	645	2400	3640	1240	+ 595	+24.8
FT-4A/64 (VARIETIES MEAN)	30	30	645	2515	3502	987	+ 342	+13.6
FT-2/4B/65	30	30	645	400	1312	912	+ 267	+66.7
GROUNDNUTS								
FT-1/63	40	40	860	4350	6005	1655	+ 795	+18.3
FT-1/63	40	80	1180	4350	6558	2238	+1058	+24.3
FT-2/5A/64 (BARBERTON)	30	30	645	6272	8243	1971	+1326	+21.1
FT-2/5A/64 (N. COMMON)	30	30	645	5335	7857	2322	+1677	+31.4
FT-2/5B/64 (MANYENNA)	30	30	645	5130	7066	1936	+1291	+25.2

* THE PRICE FOR N_2 AND P_2O_5 WERE CALCULATED TO ABOUT 13.5 AND 8.0 PIASTRES PER KILOGRAM RESPECTIVELY (L.C.I. QUOTATIONS.)

**THE PRICES PER KILOGRAM OF SORGHUM, SESAME AND GROUNDNUTS ARE ESTIMATED TO 2.0, 4.0 AND 2.7 FOR THE THREE CROPS RESPECTIVELY.

SOURCE: DOX-SUD A-35 AGRONOMY INVESTIGATIONS, DOXIADIS ASSOCIATES 1965.

TABLE 14

RESPONSE OF SORGHUM, MUNGBEAN, GUAR

TO NITROGEN & PHOSPHORUS FERTILIZER

KABA & UMM HIGLIG

1964

CROP	LOCATION	NO. OF VARIETIES	AVERAGE YIELD kg/ha +NP	-NP	CROP RAINFALL mm
SORGHUM	KABA [1	6	3363	2192	416
MUNGBEAN	UMM HEGLIG [2	5	510	290	578
GUAR	UMM HEGLIG [2	5	1930	1610	---

[1 CLAYEY PEDIPLAIN (GARDUD)
[2 SANDY SHEET (GUM-QOZ)
BOTH NEAR EL OBEID

SOURCE: PUBLICATION DOX-SUDA-35 AGRONOMY INVESTIGATIONS PUBLISHED APRIL 1965 DOXIADIS ASSOCIATES.

TABLE 15

CROP RESPONSE TO FERTILIZER

SORGHUM N/P

KABA & BANJADEED, EL OBEID 1983

CULTIVAR	YIELD			
	KABA		BANJADEED	
	W NP	W/O NP	W NP	W/O NP
IS9830	2686	2744	844	794
UM BENIN	2690	2287	416	397
SRN - 39	1484	1228	726	788
P898012	2207	1709	595	567
AVERAGE	2267	1992	645	636

SEED FROM ARC/ICRISAT/LOCAL U OF KRT/ARC STRIGA PROJECT.

FERTILIZER APPLIED 20-20-0kg/ha AS UREA & TRIPLE SUPER PHOSHATE

ANNUAL RAINFALL EL OBEID = 339mm

JUNE - SEPTEMBER RAINFALL KABA = 360mm

NOTE: KABA HAD MORE RAIN THAN BANJADEED DURING THE GROWING SEASON

TABLE 16

MILLET RESPONSE TO N/P FERTILIZER

KABA & BANJADEED, EL OBEID

1983

CULTIVAR	YIELD KABA WITH NP[3	KABA [1 W/O NP	BANJADEED WITH NP[3	BANJADEED [2 W/O NP
	kg/ha			
UGANDI	1228	1091	523	650
BALADI	1192	855	290	273
EISH BORNU	829	998	306	340
ICMS 7817	998	847	597	460
HIREHREE	984	771	340	323
AVERAGE	1046	912	411	409

[1 RECEIVED ONE HEAVY AND ONE LIGHT SHOWER AFTER FERTILIZER APPLIED

[2 RECEIVED ONE LIGHT SHOWER AFTER FERTILIZER APPLIED

[3 20-20-0 kg/ha FERTILIZER APPLIED - SIDEDRESSED AT ROOT LEVEL DURING TILLERING STAGE.(UREA AND TRIPLE SUPER PHOSPHATE)

EL OBEID ANNUAL RAINFALL = 339mm

NOTE: UGANDI, THE NEWLY INTRODUCED CULTIVAR, OUT-YIELDS LOCAL CULTIVAR, BALADI, WITH OR W/O FERTILIZER UNDER BOTH RAINFALL REGIMES.

SOURCE: 3RD PROGRESS REPORT 1983 KSU/SUDAN INTSORMIL PROJECT
SEED FROM ICRISAT / ARC / INTSORMIL / LOCAL

TABLE 17

CROP RESPONSE TO FERTILIZER

SESAME

NITROGEN / PLANT SPACING

ALLOBA (NEAR EL OBEID)

1970/71

NITROGEN LEVEL	YIELD INTER-ROW SPACING 20cm	30cm	MEAN
	kg/ha		
0 N	154.2	153.0	153.6
1 N (40kg/ha N)	164.5	242.0	203.3
MEAN	159.3	197.5	178.4

LEVEL OF SIGNIFICANCE

N 1%

SPACING 5%

N X S 5%

CULTIVAR: A - 5 - 9

SOURCE: 1970/71 RESEARCH REPORT, KORDOFAN AGRICULTURAL SURVEY AND INVESTIGATION TEAM, ARC.

EL OBEID ANNUAL RAINFALL = 262mm

TABLE 18

GROUNDNUT RESPONSE TO NITROGEN FERTILIZER

EL OBEID

1983

N LEVEL		YIELD	
		PODS	TOPS
kg/fd	kg/ha	- - - - -kg/ha- - - - -- - - - - - - -	
0	0	459	814
25	59.5	452	1221
50	119	524	904

NOTE: POD YIELD WAS NOT INCREASED SIGNIFICANTLY BY APPLICATION OF NITROGEN, BUT, HAULM GROWTH WAS INCREASED, PARTICULARLY AT THE 59.5 kg/ha LEVEL.

SOURCE:EL OBEID STATION REPORT 1983 WSARP

TABLE 19

CROP RESPONSE TO FERTILIZER

SORGHUM

NITROGEN/PHOSPHORUS

UMM RAKUBA, S. DARFUR 1983

CROP	NITROGEN LEVEL	YIELD PHOSPHORUS LEVEL			
		P_0	P_1	P_2	P_3
		- - - - - - - - - - -kg/ha - - - - - - - - - - - - - - -			
SORGHUM	N_0	115	427	198	299
SORGHUM	N_1	104	333	1041	250

TREATMENT	RATE	TREATMENT	RATE(applied as
N_0	0	P_0	0 TSP)
N_1	50kg N/ha	P_1	25 kg/ha P_2O_5
		P_2	50 kg/ha " "
		P_3	75 kg/ha " "

ANNUAL RAINFALL = 319mm

OFF-STATION TRIAL ON EXHAUSTED LAND

SOURCE: REPORT ON TRIALS CARRIED OUT AT THREE EXPERIMENTAL SITES IN SOUTH DARFUR 1983 TRIAL RESULTS WSDC/HTS FEB.84

TABLE 20

CROP RESPONSE TO FERTILIZER

SESAME / NP

UMM RAKUBA 1983

PHOSPHORUS LEVEL	YIELD NITROGEN N0	YIELD LEVEL N50
	- - - - - -kg/ha-	- - - - - - - - - - - -
P_0	100	50
P_{50}	110	260

P_{50} = 50 kg/ha

N_{50} = 50 kg/ha

P_2O_5 APPLIED AS TSP

N APPLIED AS UREA

ANNUAL RAINFALL = 319mm

SOURCE: REPORT ON A VISIT BY CONSULTANT AGRONOMIST
MAY - JULY 1984
SAVANNAH DEVELOPMENT PROJECT AUG.84. HTS.

TABLE 21

CROP RESPONSE TO FERTILIZER

SESAME / NP

DIMSU, 1981

PHOSPHORUS LEVEL	YIELD NITROGEN LEVEL N_0	N_{40}	PHOSPHORUS MAIN EFFECT*
	kg/ha		
P_0	300	500	400
P_{40}	280	640	460
NITROGEN MAIN EFFECT ***	290	570	- -

NP INTERACTION **

SIGNIFICANCE LEVEL

* 10%

** 5%

*** 1%

ANNUAL RAINFALL = 482mm

P_{40} = 40 kg/ha P_2O_5 ADDED AS TSP

N_{40} = 40kg/ha N ADDED AS UREA

SOURCE: REPORT ON A VISIT BY CONSULTANT AGRONOMIST MAY - JULY 1984 SAVANNAH DEVELOPMENT PROJECT AUG. 84 HTS.

TABLE 22

GRAIN RESPONSE TO FERTILIZER
SEED & FORAGE CROPS / NPK
UMM RAKUBA, S. DARFUR 1983

FERTILIZER	RELATIVE YIELD	
	SEED CROPS [1	FORAGE CROPS [2
0	100	100
N	119	97
P	120	139
NP	129	204
NPK	133	229

N = 50 kg OF N/ha AS UREA

P = 50 kg OF P_2O_5/ha AS TSP

K = 25 kg OF K_2O/ha AS K_2SO4

[1 GROUNDNUTS, COWPEA, SESAME

[2 COWPEAS (POONA & CALOONA) & SIRATO

ANNUAL RAINFALL = 319mm

OFF-STATION TRIAL ON EXHAUSTED LAND

SOURCE: REPORT ON TRIALS CARRIED OUT AT THREE EXPERIMENTAL SITES SOUTH DARFUR 1983 TRIAL RESULTS WSDC/HTS FEB. 84

TABLE 23

CROP RESPONSE TO FERTILIZER
SORGHUM & MILLET/PHOSPHORUS
JEBEL MARRA PROJECT AREA 1983

SOIL TYPE	AVERAGE YIELD OF SORGHUM AND MILLET*			
	PHOSPHORUS RATE** - - - - kg/ha - - - -			LEVEL OF
	0	18	55	SIGNIFICANCE
PIEDMONT ASH	1466	1594	1879	N.S.
UPPER TERRACE	1220	2145	2394	1 %
ALLUVIAL	2866	3912	3894	1 %

* ON PIEDMONT ASH SOILS THERE IS A MIXTURE OF SORGHUM AND MILLET. ON THE OTHER SOILS THE CEREAL CROP IS MOSTLY SORGHUM.

** EXPRESSED AS P_2O_5. APPLIED AS TRIPLE SUPER PHOSPHATE.

SOURCE: JMRDP 1983-84 ANNUAL REPORT ANNEX I.

TABLE 24

CROP RESPONSE TO FERTILIZER
MILLET AND SORGHUM/PHOSPHORUS
COST: BENEFIT ANALYSIS
JEBEL MARRA PROJECT AREA - 1983

SOIL TYPE	PHOSPHORUS RATE	EXTRA YIELD		EXTRA COST	NET BENEFIT	BENEFIT / COST
	kg/ha*	kg/ha		LS		
UPPER TERRACE SOILS	18	740	+370	- 39	+331	9.5
	55	939	+470	-120	+350	3.9
ALLUVIAL SOILS	18	837	+419	- 39	+380	10.7
	55	822	+411	-120	+291	3.4

GRAIN VALUED AT LS 0.50/kg
TSP VALUED AT LS 1.00/kg
EXPERIMENTAL YIELDS DISCOUNTED 20%

* RATE EXPRESSED AS P_2O_5 APPLIED AS TRIPLE SUPER PHOSPHATE, TSP.

SOURCE: JMRDP 1983-84 ANNUAL REPORT ANNEX I

TABLE 25

CROP RESPONSE TO FERTILIZER

MILLET / PHOSPHORUS

UMM RAKUBA & DIMSU 1976 - 83

	EQUIVALENT RATE OF P_2O_5	YIELD WITHOUT TSP	YIELD WITH TSP	% INCREASE IN YIELD WITH TSP
	kg/ha			
ALL 15 TRIALS*	37-50	440	880	100
ALL 9 TRIALS	18-25	460	940	104
WITH	37-50	460	1060	131
ALL 4 TRIALS	9-10	540	940	74
	18-20	540	1080	100
WITH	37-40	540	1290	139

* 6 TRIALS AT UMM RAKUBA AND 9 TRIALS AT DIMSU.

MEAN ANNUAL RAINFALL 1976-1983: UMM RAKUBA = 482mm

DIMSU = 494mm

SOURCE: REPORT ON VISIT BY CONSULANT AGRONOMIST MAY - JULY 1984 SAVANNAH DEVELOPMENT PROJECT. HTS, 1984

TABLE 26

CROP RESPONSE TO FERTILIZER
ESTIMATED COST/BENEFIT FOR TRIPLE SUPER PHOSPHATE USE
IN MILLET IN S. DARFUR (ESTIMATED 1984 PRICES)

TSP RATE	FERTILIZER COST AT SITE PLUS 20%	INCREMENTAL LABOR COST	INCREMENTAL YIELD	INCREMENTAL COST	INCREMENTAL BENEFIT	NET BENEFIT	RATIO BENEFIT/COST
kg/ha	----- Ls/ha -----		%	---- Ls/ha ----			
22 (10kg/ha P_2O_5)	17	3	74	20	133	113	6.6
44 (20kg/ha P_2O_5)	34	3	100	37	180	143	4.8

NOTES: 1984 TSP PRICE FAO KHARTOUM LS 0.47/kg
1984 LORRY TRANSPORT KHARTOUM - NYALA ESTIMATED LS 140/TON
TRANSPORT NYALA - QOZ AREAS ESTIMATED LS 40/TON
FERTILIZER COST AT SITE (INCLUDING TRANSPORT) HAS BEEN INCREASED BY 20% TO ACCOUNT FOR ADMINISTRATIVE AND HANDLING COSTS.

BASELINE MILLET YIELD ASSUMED TO BE 400 kg/ha
MILLET PRICE AT HARVEST 1983 APPROX. LS 0.55/kg
1982 APPROX. LS 0.36/kg. PRICE ASSUMED LS 0.45/kg.

PLANTING LABOR INCREASED FROM 3.6 TO 5.4 LABOR DAYS/ha. 1981 RATE FOR PLANTING WAS LS 0.8/LABOR DAY.
1984 PRICE ASSUMED TO BE DOUBLE THIS

SOURCE: REPORT ON VISIT BY CONSULTANT AGRONOMIST MAY - JULY 1984. SAVANNAH DEVELOPMENT PROJECT HTS. AUGUST 1984

TABLE 27

CROP RESPONSE TO FERTILIZER
ECONOMIC EVALUATION
SORGHUM/MILLET
JEBEL MARRA 1982

CROP	FERTILIZER*	RATE	COST	RESPONSE	BENEFIT	NET BENEFIT	BENEFIT / COST
		kg/ha	LS	kg/ha	LS	LS	
SORGHUM	TSP	43	52	672	300	248	5.8
MILLET	UREA	87	104	352	155	51	1.5

* APPLICATION RATES
TSP 20kg P_2O_5/ha
UREA 40kg N/ha

SOURCE: 1982 - 83 JMRDP ANNUAL REPORT ANNEX I

TABLE 28

CROP RESPONSE TO FERTILIZER

MILLET

NITROGEN & PLOWING

NYERTETE 1983

CULTIVATION	YIELD		
	NITROGEN		MAIN EFFECT CULTIVATION
	0	120 kg/ha UREA	
	kg/ha		
NONE	962	1007	985
PLOW (POST RAIN PRE-PLANTING)	1016	1415*	1216
MAIN EFFECT N**	989	1211	1100

SIGNIFICANCE LEVEL: * 5% ** 1%

CULTIVAR : BAYUUDA

ANNUAL RAINFALL = 470mm

SOURCE : JMRDP 1983 - 84 ANNUAL REPORT ANNEX I

TABLE 29

CROP PRODUCTION STATISTICS
YIELD PER UNIT AREA (kg/ha)
KORDOFAN REGION
10 YR. RUNNING MEANS
ENDING IN INDICATED YEAR

YEAR	MILLET	SORGHUM	GROUNDNUTS	SESAME
	- - - - - - - - - - - kg/ha - - - - - - - - - - - -			
1970*	528	726	641	310
1971	471	696	594	284
1972	432	657	532	271
1973	406	622	489	256
1974	368	608	487	237
1975	344	596	468	226
1976	334	607	483	222
1977	323	601	476	219
1978	320	620	492	218
1979	303	586	487	213
1980	299	586	517	199
1981	287	590	583	200
1982	284	597	585	194
1983	283	580	573	191

1970* = MEAN FOR 10 YEAR PERIOD 1961/62 - 1970/71

SOURCE: AREA, YIELD AND PRODUCION 9 MAJOR CROPS
SUDAN 1961/62 - 1983/84
DEPARTMENT OF STATISTICS PLANNING & AGRICULTURAL
ECON. ADMIN., MIN. OF AGR. MAY 1984

JJR 1 NOV. 84

TABLE 30

CROP PRODUCTION STATISTICS
RELATIVE YIELD PER UNIT AREA
KORDOFAN REGION
10 YEAR RUNNING MEANS
NORMALIZED TO 1970 (i.e. 1961/62-1970/71 PERIOD)

YEAR	MILLET	SORGHUM	GROUNDNUTS	SESAME
1970*	100	100	100	100
1971	89	96	93	92
1972	82	90	83	87
1973	77	86	76	83
1974	70	84	76	76
1975	65	82	73	73
1976	63	84	75	72
1977	61	83	74	71
1978	61	85	77	70
1979	57	81	76	69
1980	57	81	81	64
1981	54	81	91	65
1982	54	82	91	63
1983	54	80	89	62

1970* = NORMALIZED MEAN FOR 10 YEAR PERIOD 1961/62 - 1970/71

SOURCE: AREA, YIELD AND PRODUCTION 9 MAJOR CROPS
SUDAN 1961/62 - 1983/84
DEPARTMENT OF STATISTICS PLANNING & AGRICULTURAL
ECON. ADMIN., MIN. OF AGR. MAY 1984

JJR 1 NOV. 84

TABLE 31

CROP PRODUCTION STATISTICS
YIELD PER UNIT AREA (kg/ha)
DARFUR REGION
10 YR. RUNNING MEANS ENDING
IN YEAR INDICATED

YEAR	MILLET	SORGHUM	GROUNDNUTS	SESAME
	kg/ha			
1970*	580	867	694	254
1971	603	872	722	250
1972	590	876	732	237
1973	558	835	740	246
1974	551	819	758	262
1975	553	830	764	248
1976	550	843	781	226
1977	524	850	759	215
1978	515	856	785	217
1979	493	768	755	206
1980	467	699	747	199
1981	452	683	700	202
1982	433	658	666	196
1983	423	608	623	191

1970* = MEAN OF 10 YEAR PERIOD 1961/62 - 1970/71

SOURCE: AREA, YIELD AND PRODUCTION9 MAJOR CROPS
SUDAN 1961/62 - 1983/84
DEPT. OF STAT. PLANNING & AGR. ECON. ADMIN.
MIN. OF AGR. MAY 1984

JJR 31 OCT. 84

TABLE 32

CROP PRODUCTION STATISTICS

RELATIVE YIELD PER UNIT AREA

DARFUR REGION

10 YEAR RUNNING MEANS

NORMALIZED TO 1970 (i.e. 1961/62 - 1970/71 PERIOD)

YEAR	MILLET	SORGHUM	GROUNDNUTS	SESAME
1970*	100	100	100	100
1971	104	101	104	98
1972	102	101	105	93
1973	96	96	107	97
1974	95	94	109	103
1975	95	96	110	98
1976	96	97	113	89
1977	90	98	109	85
1978	89	99	113	85
1979	85	88	109	81
1980	81	81	108	78
1981	78	79	101	80
1982	75	76	96	77
1983	73	70	90	75

1970* = NORMALIZED MEAN FOR 10 YEAR PERIOD 1961/62-1970/71

SOURCE: AREA, YIELD AND PRODUCTION 9 MAJOR CROPS
SUDAN 1961/62 - 1983/84
DEPT. OF STAT. PLANNING & AGR. ECON. ADMIN.,
MIN. OF AGR. MAY 1984

JJR 1 NOV. 84

TABLE 33

IMPROVED CULTIVARS

MILLET

KABA (NEAR EL OBEID)

1974/75

FAO REGIONAL PEARL MILLET NURSERY

CULTIVAR/LINE	ORIGIN	YIELD (RANK)	PLANT POPULATION	DAYS TO 50% FLOWERING	PLANT HEIGHT
		kg/ha	(000)/ha	da	cm
LOCAL CHECK	SUDAN	731(1)	60	61	140
SERERE 2A	UGANDA	522(2)	40	57	152
SERER 10 LA X SERERE 17	UGANDA	466(3)	31	54	167
23A X SERERE 2 A	UGANDA	429(4)	21	54	134
W.P. COMP.	NIGERIA	374(5)	38	60	161
EX. BORNU	NIGERIA	361(6)	41	64	171
SERERE COMP.	UGANDA	342(7)	32	57	142
MEAN (12 ENTRIES)		349	34	59	145

RAINFALL (EL OBEID) = 346mm

SOURCE: 1974/75 ANNUAL REPORT OF THE EL OBEID SUB-STATION. (Prepared by El Hag H. Abu El Gasim)

TABLE 34

IMPROVED CULTIVARS

MILLET

KABA (NEAR EL OBEID)

1975/76

CULTIVAR	ORIGIN	YIELD	(RANK)	PLANT POPULATION	PLANT HEIGHT
		kg/ha		(000)/ha	cm
FAKI ABYAD	SUDAN (DARFUR)	1844	(1)	73	182
SERERE 10 LA X X SERERE 17	UGANDA	1494	(2)	67	168
SOUNA 3	SENEGAL	1377	(3)	66	168
EX. BORNU	NIGERIA	1204	(4)	63	154
NAIN COMP.	SENEGAL	1115	(5)	72	154
DUKHN RAMADI	SUDAN (DARFUR)	1096	(6)	86	162
SERERE 17	UGANDA	1035	(7)	71	157
DEMBI	SUDAN (KORDOFAN)	1030	(8)	80	180
W.P. COMP.	NIGERIA	974	(9)	64	164
KORDOFANI	SUDAN (KORDOFAN)	835	(10)	82	185
MEAN (10 ENTRIES)		1199		73	167

EL OBEID RAINFALL = 198 mm

SOURCE: 1975/76 ANNUAL REPORT OF THE EL OBEID SUB-STATION. (Prepared by El Hag H. Abu El Gasim)

TABLE 35

IMPROVED CULTIVARS

MILLET

NYERTETE, JEBEL MARRA 1982

CULTIVAR	YIELD kg/ha	REMARKS
BAYUUDA	1081 (1)	LOCAL CULTIVAR (DARFUR)
ICMS 7935	945 (2)	ICRISAT LINE
ICMS 7817	939 (3)	ICRISAT LINE
IVS 8206	939 (4)	ICRISAT LINE
IVS H78	894 (5)	ICRISAT LINE
ICMS 7704	868 (6)	ICRISAT LINE
KORDOFANI	473 (20)	LOCAL CULTIVAR FROM KORDOFAN
UGANDI	469 (21)	INTRODUCED LINE IN KORDOFAN

ANNUAL RAINFALL = 443 mm

( ) = RANK

TOTAL ENTRIES = 21

SOURCE: 1982-1983 JMRDP ANNUAL REPORT ANNEX I

TABLE 36

IMPROVED CULTIVARS

MILLET

DIMSU, S. DARFUR 1983

CULTIVAR	YIELD	RANK
	kg/ha	
INMB - 33	771	(1)
IVS H 78	521	(2)
ICMS 7817	503	(3)
IVS P77	491	(4)
KORDOFANI	482	(5)
UGANDI	417	(6)
SCI P8008	80	(15)

SEED SOURCE ICRISAT/ARC

ANNUAL RAINFALL = 358 mm

SOURCE: REPORT ON TRIALS CARRIED OUT AT THREE EXPERIMENTAL SITES IN SOUTH DARFUR 1983 TRIAL RESULTS WSDC / HTS FEBRUARY 1984

TABLE 37

IMPROVED CULTIVARS

MILLET

KABA, EL OBEID 1983

ENTRY	YIELD	RANK	PLT. POPULATION	HEADS/PLT.
	kg/ha		000/ha	NO.
ICMS 7817	640	(1)	20	3.3
IVSH 78	467	(2)	17	2.6
KORDOFANI	460	(3)	14	3.0
KMDC	450	(4)	7	4.1
INMB 33	419	(5)	19	1.5
ICMS 7835	388	(7)	12	3.7
ITV 8003	373	(8)	12	1.1
SCI P8001	295	(10)	7	2.2
UGANDI	107	(14)	7	1.4

TOTAL ENTRIES (RECORDED) = 14

PLANTED 4 JULY 1983

RAINFALL JULY - SEPT. = 357 mm

SOURCE: EL OBEID STATION REPORT, WSARP. 1983

TABLE 38

IMPROVED CULTIVARS

MILLET

NYERTETE 1983

NATIONAL VARIETY YIELD TRIAL (PMNT-7)

LINE	YIELD**	(RANK)
	kg/ha	
NYERTETE BAYUUDA	1374	(1)
JMP/149 (KALOKITTING)	1261	(2)
JMP/199 (ABATA)	1259	(3)
JMP/137 (SW JEBEL MARRA)	1231	(4)
* ITV 8003	1181	(5)
JMP/167 (BELDONG)	1180	(6)
JMP/154 (NABAQIEH)	1165	(7)
* IVS 8206	1083	(8)
* IVS 1178	1065	(9)
* INMB 33	992	(10)
LOCAL CHECKS		
* UGANDI	919	(13)
KORDOFANI	684	(19)

TOTAL ENTRIES = 21

* ICRISAT INTRODUCED MATERIAL

ANNUAL RAINFALL = 470 mm

** YIELDS TAKEN FROM SOURCE 1. YIELDS IN SOURCE 2 ARE 1.33 X GREATER

SOURCES: 1.JMRDP 1983 - 84 ANNUAL REPORT ANNEX I

2.PEARL MILLET IMPROVEMENT PROGRAM IN SUDAN, ICRISAT/ARC (Prepared by R.P.Jain)

TABLE 39

IMPROVED CULTIVARS

SORGHUM

KABA (NEAR EL OBEID)

1974/75 1975/76

CULTIVAR	YIELD	(RANK)	PLANT POPULATION	YIELD	(RANK)	PLANT POPULATION
	1974/75			1975/76		
	kg/ha		(000)/ha	kg/ha		(000)/ha
DWARF WHITE MILO	1141	(1)	117	436	(7)	116
NES - 858	1116	(2)	121	284	(12)	97
CROSS 5:10/7/7	922	(3)	101	489	(6)	81
CROSS 12:9/6/1	908	(4)	123	223	(14)	98
FETERITA MAATUG 7	882	(5)	124	285	(11)	101
GADEM EL HAMAM (33/2/1)	824	(7)	120	304	(9)	112
T.U.B. 7 (CHECK)	736	(8)	109	659	(2)	111
T.U.B. 22 (CHECK)	610	(9)	119	512	(5)	88
DABAR (1/1/1/1)	572	(11)	129	131	(16)	92
SAFRA HABASHEYA (LOCAL CHECK)	320	(15)	103	255	(13)	95
CROSS 5: 10/7/8	520	(12)	81	736	(1)	99
MEAN (16 ENTRIES)	699		117	400		101

EL OBEID RAINFALL

1974 = 346 mm

1975 = 198 mm

SOURCE: 1974/75 1975/76 ANNUAL REPORTS OF THE EL OBEID SUB-STATION.

TABLE 40

IMPROVED CULTIVARS
SORGHUM
KABA (NEAR EL OBEID)
1975 / 76
FAO REGIONAL COOPERATIVE TRIAL

CULTIVAR/LINE	ORIGIN	YIELD	(RANK)	POPULATION DENSITY
		kg/ha		(000)/ha
GIZA 3	EGYPT	642	(1)	46
CE 90-16-3	SENEGAL	628	(2)	42
5 D X 157/19/3	UGANDA	535	(3)	33
C SH-1	INDIA	431	(4)	52
5 D X 135/13/1/3/1	UGANDA	413	(5)	51
T.U.B. 7	LOCAL CHECK	377	(7)	57
MEAN (12 ENTRIES)		401		43

ANNUAL RAINFALL = 198 mm
SOURCE: 1975/76 ANNUAL REPORT OF THE EL OBEID SUB-STATION

TABLE 41

LOCAL VERSUS INTRODUCED CULTIVARS

SORGHUM

KADUGLI 1979 & 1980

CULTIVAR	SOURCE	YIELD kg/ha 1979	(RANK)	1980	(RANK)
ERIANA	LOCAL	1899	(2)	1699	(3)
GADAM EL HAMAM	INTRODUCED	1745	(3)	1892	(2)
T.U.B.	INTRODUCED	1066	(7)	2775	(1)
KARAMAKA	LOCAL	2030	(1)	447	(7)
OEFEIRA	LOCAL	1542	(4)	740	(5)
ELBEIDA	LOCAL	1233	(6)	819	(4)
DABAR	INTRODUCED	1380	(5)	709	(6)

ANNUAL RAINFALL, KADUGLI

1979 = 397 mm

1980 = 532 mm

SOURCE: KADUGLI STATION ANNUAL REPORT 1980-1981

TABLE 42

LOCAL CULTIVAR EVALUATION

SORGHUM

TELO, (KADUGLI) 1982

CULTIVAR	YIELD		(RANK)	MATURITY	HEIGHT
	kg/fd	kg/ha		da	cm
KURI 288	1106	2632	(1)	118	235
KULUM 283	871	2073	(2)	132	184
TABRORO	737	1754	(5)	117	175
LUGAGO 285	566	1347	(12)	137	206
GADEM EL HAMAM*	536	1273	(13)	119	113
DABAR*	457	1088	(16)	127	116

* INTRODUCED CULTIVARS

TOTAL ENTRIES = 19

ANNUAL RAINFALL, KADUGLI = 561 mm

SOURCE: KADUGLI STATION ANNUAL REPORT 1982 - 1983

TABLE 43

IMPROVED CULTIVARS

SORGHUM

JEBEL MARRA 1982

LOCATION	YIELD	
	DABAR [1	FASIIKH [2
	-------kg/ha-------	
JEBEL AREA	776	842
UPPER VALLEYS	1101	946*
LOWER VALLEYS	1237	1183

* SIGNIFICANT AT 5% LEVEL

[1 EARLY MATURING INTRODUCED CULTIVAR

[2 LATE MATURING LOCAL CULTIVAR

NOTE: ONLY 2 OF 171 FARMERS INTERVIEWED CONSIDERED DABAR INFERIOR TO LOCAL LINES.

FARMERS REASONS FOR ACCEPTABILITY OF DABAR:

- EARLY MATURING
- MORE RELIABLE IN POOR SEASONS
- PRODUCES GOOD TASTING WHITE FLOUR
- GOOD YIELD
- RESISTANT TO PESTS & DISEASES

SOURCE: JMRDP ANNUAL REPORT 1982-1983 ANNEX I

TABLE 44

IMPROVED CULTIVARS

SORGHUM

JEBEL MARRA 1983

LOCATION	OBSERVATIONS	YIELD	
		EARLY MATURING INTRODUCED LINE [1	LATE MATURING LOCAL LINE
		- - - - - - - - - - kg/ha	- - - - - - - - - -
NYERTETE	5	3060	2440
DANKUCH	13	2150	2610*
WADI SALEH	9	3552	2366*

* STATISTICALLY SIGNIFICANT AT 5% LEVEL

[1 GADEM EL HAMAM OR DABAR

ANNUAL RAINFALL

NYERTETE = 470 mm

DANKUCH = 295 mm

WADI SALEH NO DATA

STATIONS NEAR WADI SALEH

MUKJAR = 612 mm

BINDISI = 621 mm

SOURCE: JMRDP 1984 AG. REVIEW

TABLE 45

IMPROVED CULTIVARS

SORGHUM

UTILIZATION CHARACTERISTICS

JEBEL MARRA PROJECT AREA 1983

NATIONAL YIELD TRIAL ENTRY	UTILIZATION CHARACTERISTICS GRAIN COLOR	ASIIDA COLOR	ASIIDA FLAVOR	DAYS TO 50% FLOWERING
CROSS 34:18	5	5	5	79
CROSS 35:05	5	5	5	87
CROSS 54:36	4	4	5	69
CROSS 54:43	3	4	5	74
DABAR	2	5	5	80
FASIIKH (DANKUCH)	2	4	4	87
CROSS 43:33	2	5	5	72
SPV - 138	1	4	4	80
M - 90393	1	4	5	71
CROSS 51:16	1	4	5	70

RATING

1	PURE WHITE	VERY LIGHT	POOR
5	YELLOWISH WHITE	MODERATELY LIGHT	EXCELLENT

SOURCE: JMRDP 1983 - 84 ANNUAL REPORT ANNEX I

TABLE 46

IMPROVED SORGHUM CULTIVARS

TELO, (KADUGLI)

1983 NATIONAL VARIETY TRIAL

CULTIVAR/PEDIGREE	(RANK)	AVERAGE YIELD kg/ha	
SU CR 35:20	(1)	1052	
SU CR 40:36	(2)	1032	
DABAR 1/1	(8)	751	POPULAR INTRODUCED CULTIVARS
GADEM EL HAMAM	(9)	733	
SU CR 36:81	(18)	478	
SPV 138	(24)	285	

SEED FROM ARC

SELECTED ENTRIES SHOWN IN TABLE

TOTAL NO. OF ENTRIES 24

RAINFALL JULY - OCTOBER = 345 mm

SOURCE: AGRONOMY REPORT 1983, WSARP KADUGLI STATION

TABLE 47

IMPROVED CULTIVARS

SORGHUM

TELO, (KADUGLI) 1983

NATIONAL HYBRID TRIAL

PEDEGREE	AVERAGE YIELD	(RANK)
	- -kg/ha - -	
296 AX SU CR 67:98/18	1470	(1)
954066 AX SU CR 51:32/28	14[illegible]	(2)
HAGEEN DURA #1	1029 ←RELEASED HYBRID	(16)
623 AX (EC 64734 XE 35-1) 6-2-3	751	(24)

RAINFALL JULY - OCTOBER = 345 mm

SELECTED ENTRIES SHOWN

TOTAL NO. OF ENTRIES = 24

SEED FROM ARC/ICRISAT COOP. PROGRAM

SOURCE: 1983 AGRONOMY REPORT KADUGLI STATION WSARP

TABLE 48

IMPROVED GROUNDNUT CULTIVARS

KABA & GOZ ASHGAR (NEAR EL OBEID)

1974/75, 1975/76

CULTIVAR	YIELD 1974/75				YIELD 1975/76	
RAINFALL	KABA 346*	(RANK)	G/ASHGAR 379	(RANK)	KABA 198*	(RANK)
	kg/ha					
U/4/47/23	2628	(1)	705	(8)	1134	(1)
U/4/47/24	2436	(2)	690	(9)	734	(4)
U/4/4/20	2233	(3)	749	(4)	691	(7)
U/4/47/25	2102	(4)	872	(2)	719	(5)
U/4/47/2	2044	(5)	875	(1)	747	(3)
U/4/47/16	1834	(7)	785	(3)	710	(6)
U/4/4/7	1834	(7)	749	(4)	837	(2)
BARBERTON (U/4/4/22)	1629	(10)	676	(10)	536	(10)
MEAN (10 ENTRIES)	2047		752		737	

KABA IS 5 MILES SOUTH OF EL OBEID ON GARDUD SOILS.

GOZ ASHGAR IS 21 MILES EAST OF EL OBEID ON GOZ SOILS.

* EL OBEID DATA

SOURCE: ANNUAL REPORTS, EL OBEID RESEARCH STATION 1974/75 & 1975/76.

TABLE 49

IMPROVED CULTIVARS

GROUNDNUTS

TELO (KADUGLI), EL OBEID, EL FUDA & DIMSU

1983

NATIONAL VARIETY TRIAL I

CULTIVAR	IN SHELL YIELD							
	EL FUDA (S.KORDOFAN)		DIMSU (S.DARFUR)		KADUGLI (S.KORDOFAN)		EL OBEID (N.KORDOFAN)	
	kg/ha							
COMET	1381	(4)	762	(1)	640	(11)	500	(15)
SPANHOMA	1193	(10)	551	(10)	590	(12)	708	(1)
EC - 5	1896	(1)	753	(3)	1413	(1)	677	(2)
EM - 9	1381	(4)	755	(2)	1133	(2)	596	(3)
GFA SPANISH	1251	(8)	503	(13)	929	(3)	525	(11)
PRONTO (EM-12)	1079	(14)	550	(11)	670	(10)	512	(13)
BARBERTON*	861	(16)	553	(9)	678	(9)	427	(16)
SPANTEX	1209	(9)	469	(15)	427	(15)	542	(8)
ICGS-81 NCR-21-11	1702	(2)	385	(16)	687	(8)	504	(14)
DIXIE SPANISH	1096	(3)	525	(12)	424	(16)	594	(5)

* MOST WIDELY PLANTED CULTIVAR IN W. SUDAN

( ) = RANK

TOTAL ENTRIES = 18 (2 DROPPED FROM ANALYSES DUE TO LOW SEED VIABILITY)

ANNUAL RAINFALL: EL FUDA = 449 mm
DIMSU = 358 mm
KADUGLI (SERAF) = 405 mm (JULY - OCT. ONLY)
EL OBEID = 339 mm

SOURCES: KADUGLI STATION AGRONOMY REPORT 1983
EL OBEID STATION REPORT 1983
REPORT ON TRIALS CARRIED OUT AT THREE EXPERIMENTAL SITES IN SOUTH DARFUR 1983 TRIAL RESULTS WSDC/HTS FEBRUARY 1984
ANNUAL REPORT 1983-84 GROUNDNUTS,. SESAME, SOYBEANS (IDRC OILSEEDS PROJECT 3-P-80-0102) ARC

TABLE 50

IMPROVED CULTIVARS

GROUNDNUTS

EL FUDA, TELO (KADUGLI) AND EL OBEID

1983

NATIONAL VARIETY TRIAL II

CULTIVAR/LINE	IN SHELL YIELD EL FUDA (S. KORDOFAN)		KADUGLI		EL OBEID	
	kg/ha					
ICGS81-20	1159	(4)	1894	(1)	583	(3)
ICGS81-18	1572	(1)	1472	(2)	592	(2)
BARBERTON*	1142	(7)	1282	(7)	506	(8)
ICGS81-33	1000	(14)	1000	(16)	517	(7)
ICGS81-23	1147	(6)	732	(21)	600	(1)
ICGS81-19	1329	(3)	706	(22)	421	(19)
PI 295210	892	(19)	1003	(15)	369	(22)
ICGS81-44	728	(22)	1414	(5)	502	(10)

* MOST WIDELY PLANTED CULTIVAR IN W. SUDAN

( ) = RANK

TOTAL ENTRIES = 22

SEED FROM ARC/ICRISAT

ANNUAL RAINFALL: EL FUDA = 449 mm

KADUGLI (SERAF) = 405 mm (JULY - OCT. ONLY)

EL OBEID = 339 mm

SOURCE: KADUGLI & EL OBEID STATION REPORTS 1983

ANNUAL REPORT 1983-84 GROUNDNUTS, SESAME, SOYBEANS. (IDRC OILSEEDS PROJECTS 3-P-80-D102) ARC

TABLE 51

IMPROVED CULTIVARS

SESAME

KABA & GOZ ASHGAR (NEAR EL OBEID)

1974/75 & 1975/76

CULTIVAR		1974/75 KABA 346* YIELD	(RANK)	G/ASHGAR 379 YIELD	(RANK)	1975/76 KABA 198* YIELD	(RANK)	RAINFALL (mm)
HERAIHRI	(LOCAL)	302	(1)	346	(2)	194	(12)	
BALADI	(LOCAL)	178	(15)	355	(1)	345	(1)	
A - 5 - 18		290	(2)	331	(3)	297	(2)	
A - 5 - 9 ***		278	(3)	266	(5)	41	(22)**	
CROSS 28/4		271	(5)	271	(4)	184	(16)	
A - 1 - 9		162	(17)	240	(10)	246	(5)	
A - 2 - 10		274	(4)	259	(7)	158	(18)	
CROSS 30/1		191	(13)	198	(20)	266	(3)	
A - 2 - 15		200	(11)	236	(12)	260	(4)	
MEAN (22 ENTRIES)		206		243		198		

KABA IS 5 MILES SOUTH OF EL OBEID ON GARDUD SOILS

GOZ ASHGAR CENTRAL FORESTRY RESERVE IS 20 MILES EAST OF EL EBEID ON GOZ SOILS.

* EL OBEID DATA
** SLIGHT SHATTERING BEFORE HARVEST
*** WHITE COLORED SEED

SOURCE: ANNUAL REPORTS, EL OBEID RESEARCH STATION 1974/75 & 1975/76

TABLE 52

IMPROVED CULTIVARS

COWPEAS

KABA (EL OBEID) & TELO (KADUGLI)

1983

CULTIVAR	SEED SOURCE	KABA		TELO	
		YIELD	(RANK)	YIELD	(RANK)
		kg/ha		kg/ha	
CHINO M I	USA	705	(1)	178	(13)
CALIFORNIA BLACKEYE #5	USA	625	(2)	268	(8)
1-12-3	USA	500	(3)	337	(3)
7964	USA	480	(4)	113	(16)
1-2-1	USA	468	(5)	239	(9)
CHINO E I	USA	425	(6)	136	(15)
3-4-13	USA	355	(7)	198	(11)
8006	USA	208	(8)	173	(14)
LOCAL - GAMBARO	SUDAN	165	(9)	---	----
LOCAL - GARNEL KABISH	SUDAN	135	10)	---	----

SEED SOURCE: INTRODUCED LINES PROVIDED BY BEAN & COWPEA CRSP

TOTAL ENTRIES : KABA = 10
: TELO = 19

ANNUAL RAINFALL : KABA = 382 mm
: TELO = 345 mm (JULY - OCT.)

SOURCE: KADUGLI & EL OBEID STATION WSARP 1983 REPORTS

TABLE 53

IMPROVED CULTIVARS

COWPEA

TELO (KADUGLI)

1983

VARIETY	ORIGIN	YIELD	RANK
		kg/ha	
58 - 57	SENEGAL	391	(1)
M - 66	KENYA	344	(2)
1 - 12 - 3	USA	337	(3)
M - 80	KENYA	331	(4)
58 - 185	SENEGAL	326	(5)
GOROM - GOROM	U. Volta	297	(6)
LOCAL #1	SUDAN	52	(18)
LOCAL #2	SUDAN	21	(19)

SELECTED ENTRIES SHOWN.

TOTAL NO. OF ENTRIES = 19
MOST OF ENTRIES WERE PROVIDED BY THE BEAN & COWPEA CRSP.

RAINFALL JULY - OCT. = 345 mm

SOURCE: 1983 AGRONOMY REPORT KADUGLI, WSARP.

TABLE 54

IMPROVED CULTIVARS

COWPEAS

DIMSU, S. DARFUR

1983

CULTIVAR	YIELD	RANK
	kg/ha	
TUX 3236-01G	823	(1)
TUX 4654-44E	793	(2)
IT 82E-27	592	(3)
IT 82E-3	589	(4)
LOCAL	379	(10)
TUX 4659-03E	329	(15)
IT 81D-1151	116	(18)

TOTAL ENTRIES = 18

SEED SOURCE: IITA

NOTE: ALTHOUGH SOME ARE HIGHER YIELDING NONE OF THE IITA LINES HAVE A COLOR OR COOKING CHARACTERISTIC COMPARABLE TO LOCAL CULTIVAR.

ANNUAL RAINFALL= 358 mm

SOURCE: REPORT ON TRIALS CARRIED OUT AT THREE EXPERIMENTAL SITES IN SOUTH DARFUR 1983 TRIAL RESULTS.
WSDC/HTS FEBRUARY 1984

TABLE 55

IMPROVED CULTIVARS
SOYBEAN, MUNGBEAN AND COWPEA
TELO (KADUGLI)
1983

CROP	SEED SOURCE	MEAN YIELD OF TOP 5 LINES	TOTAL ENTRIES TESTED
MUNGBEAN	AVRDC	596 kg/ha	22
SOYBEAN	INTSOY/AVRDC	350 kg/ha	33
COWPEA	IITA/B&C. CRSP	346 kg/ha	19

RAINFALL JULY - OCTOBER = 345 mm

SOURCE: ANNUAL AGRONOMY REPORT KADUGLI STATION, WSARP 1983.

TABLE 56

CULTURAL PRACTICES
SEED SIZE
SORGHUM & MILLET
GREENHOUSE, EL OBEID
1983

CROP	CULTIVAR	SOIL TYPE	SEEDLING HEIGHT @ 14 DAYS REGULAR SEED	LARGER SEED [1
			- - - - - - - cm	- - - - - - -
SORGHUM	IS 9830	CLAY	24.6	25.0
SORGHUM	IS 9830	SAND	12.4	17.9
MILLET	BALADI-WHITE	CLAY	17.9	24.5
MILLET	BALADI-WHITE	SAND	7.7	16.6

[1 FROM HEAD THAT HAD TWO-THIRDS CUT OFF AT FLOWERING

ALL SEEDS PLANTED AT 3 cm DEPTH

NOTE: BALADI-WHITE SEEDS FROM HEADS WITH TWO-THIRDS REMOVED HAD 29.6% GREATER SEED WEIGHT THAN SEEDS FROM WHOLE HEADS.

IS 9830 SEEDS FROM HEADS WITH TWO-THIRDS REMOVED WERE 21.6% GREATER SEED WEIGHT THAN SEEDS FROM WHOLE HEADS.

SEED SOURCE: LOCAL & ARC/U. OF KRT. STRIGA PROJECT.

SOURCE : 3RD PROGRESS REPORT KSU/SUDAN INTSORMIL PROJECT 1983.

TABLE 57

CULTURAL PRACTICES
PLANT SPACING
MILLET
WAD ASHANA (NORTH OF EL OBEID)
1970/71

CULTIVAR	YIELD INTER-ROW SPACING 50 cm	100 cm	MEAN
	kg/ha		
KORDOFANI	140	266	203
JABALI	76	190	133
MEAN	108	228	168

GRAIN YIELD OF KORDOFANI STATISTICALLY GREATER THAN THAT OF JABALI AT 0.1% (P=.001) LEVEL.

EL OBEID ANNUAL RAINFALL = 262 mm.

SOURCE: 1970/71 RESEARCH REPORT KORDOFAN AGRUCULTURAL SURVEY AND INVESTIGATION TEAM, ARC.

TABLE 58

CULTURAL PRACTICES

PLANT SPACING

MILLET

KABA (NEAR EL OBEID)

1975/76

CULTIVAR/LINE	TRIAL I YIELD	TRIAL I SPACING AT HARVEST	TRIAL II YIELD	TRIAL II SPACING AT HARVEST
	kg/ha	(000)/ha	kg/ha	(000)/ha
SERERE 10 LA X SERERE 17	1494	66	907	58
W.P. COMP.	974	64	711	102
EX. BORNU	1204	63	629	92
KORDOFANI	835	82	550	114
MEAN	1127	69	699	92
SPACING AT PLANTING		113	SPACING AT PLANTING	148

TRIAL I: TRIAL OF SIX EXOTIC AND FOUR LOCAL MILLET LINES. (60cm BETWEEN ROWS/15cm BETWEEN PLANTS = 113,000 PLANTS PER HECTARE).

TRIAL II: FAO REGIONAL PEARL MILLET YIELD NURSERY (45cm BETWEEN ROWS/15cm BETWEEN PLANTS = 148,000 PLANTS PER HECTARE).

EL OBEID RAINFALL = 198 mm

SOURCE: 1975/76 ANNUAL REPORT OF THE EL OBEID SUB-STATION.

TABLE 59

CULTURAL PRACTICES
INTER-ROW SPACING & PLANTS PER HOLE
SORGHUM
ALLOBA (NEAR EL OBEID)
1970/71

PLANT POPULATION AT HARVEST

INTER-ROW SPACING	PLANTS PER HOLE ONE	TWO	MEAN
CM	(000)/ha		
50	72.7	142.7	107.7
100	39.2	67.8	53.5
MEAN	55.9	105.3	80.6

DIFFERENCES IN INTER-ROW SPACING AND PLANTS PER HOLE.
TREATMENTS STATISTICALLY SIGNIFICANT AT 0.1% (P=.001) LEVEL.

CULTIVARS USED: WAD AKAR, UM BENEIN 7 AND ZENNARI

1970 EL OBEID RAINFALL = 262 mm

SOURCE: 1970/71 RESEARCH REPORT KODOFAN AGRICULTURAL SURVEY AND INVESTIGATION TEAM, ARC.

TABLE (

CULTURAL PRACTICES

INTER-ROW SPACING & PLANTS PER HOLE

SORGHUM

ALLOBA (NEAR EL OBEID)

1970/71

GRAIN YIELD

INTER-ROW SPACING	PLANTS PER HOLE ONE	TWO	MEAN
cm	kg/ha		
50	41.6	32.6	37.1
100	71.6	44.3	57.0
MEAN	56.6	38.6	47.6

CULTIVARS : WAD AKAR, UM BENEIN 7, ZINNARI

MEAN GRAIN YIELD : 32.6 , 99.7 , 10.5
kg/ha

VARIETAL DIFFERENCES WERE SIGNIFICANT AT THE 0.1% (P=001) LEVEL

ANNUAL RAINFALL (EL OBEID) = 262 mm

SOURCE: 1970/71 RESEARCH REPORT, KORDOFAN AGRICULTURAL SURVEY AND INVESTIGATION TEAM, ARC.

TABLE 61

CULTURAL PRACTICES

INTER-ROW SPACING

SORGHUM

WAD ASHANA (NORTH OF EL OBEID)

1970/71

YIELD

INTER-ROW SPACING	CULTIVARS WAD AKAR	UM BENEIN 7	MEAN
cm	kg/ha		
50	470	352	411
100	465	498	482
MEAN	467	425	446

SPACING AND INTERACTION OF VARIETY & SPACING STATISTICALLY SIGNIFICANT AT 5% LEVEL.

EL OBEID RAINFALL 1970 = 262 mm

SOURCE: 1970/71 RESEARCH REPORT KORDOFAN AGRICULTURAL SURVEY AND INVESTIGATION TEAM, ARC.

TABLE 62

CULTURAL PRACTICES
PLANT SPACING
GROUNDNUTS
WAD ASHANA (NORTH OF EL OBEID)
1970/71

YIELD

CULTIVAR	INTER-ROW SPACING 20 cm	30 cm	MEAN
	kg/ha		
BARBERTON	420	562	491
NATAL	470	491	480
LIBYAN	426	430	428
LOCAL (RUNNER)	40	163	101
MEAN	339	411	375

SPACING SIGNIFICANT AT 5% LEVEL

EL OBEID RAINFALL = 262 mm

SOURCE: 1970/71 RESEARCH REPORT KORDOFAN AGRICULTURAL SURVEY AND INVESTIGATION TEAM, ARC.

TABLE 63

CULTURAL PRACTICES

PLANT SPACING

SESAME

WAD ASHANA (NORTH OF EL OBEID)

1970/71

CULTIVAR	SOURCE	MATURITY	YIELD PLANT SPACING 20cm	30cm	MEAN
			- - - - - - - - kg/ha - - - - - -		
HIRACHERI	LOCAL	EARLY	296	332	314
A - 5 - 9	ARC	EARLY	244	303	274
A - 1 - 10	ARC	EARLY	168	157	163
WAD EL NEIL (HEAVY BLACK)	ARC	LATE	43	71	57
DARI	LOCAL	LATE	8	43	25
MEAN			152	181	166

EFFECT OF SPACING STATISTICALLY SIGNIFICANT AT 5% LEVEL ON A-5-9 ONLY

ANNUAL RAINFALL, EL OBEID = 262 mm

SOURCE: 1970/71 RESEARCH REPORT KORDOFAN AGRICULTURAL SURVEY AND INVESTIGATION TEAM, ARC.

TABLE 64

CULTURAL PRACTICES
NITROGEN/SPACING
KERKADEH
ALLOBA (NEAR EL OBEID)
1970/71

FRUIT YIELD (AIR DRY WT.)

NITROGEN LEVEL	INTER-ROW SPACING 50cm	100cm	MEAN
	kg/ha		
0 N	15.0	41.2	28.1
0.5 N (20kgN/ha)	20.7	26.9	23.8
MEAN	17.8	34.0	25.9

ANNUAL RAINFALL (EL OBEID) = 262 mm

CULTIVARS : RAHAD AND NUHUD

EFFECT OF SPACING SIGNIFICANT AT 1% LEVEL

SOURCE: 1970/71 RESEARCH REPORT, KORDOFAN AGRICULTURAL SURVEY AND INVESTIGATION TEAM, ARC.

TABLE 65

CULTURAL PRACTICES

PLANT SPACING

SESAME

EL FUDA

1980/81

WITHIN ROW SPACING	YIELD	PLANT POPULATION
cm	kg/ha	(000)/ha
17.5	514	86.9
12.0	505	101.2
7.5	493	138.0
SE±	88	
C.V.%	35	

CULTIVAR : ZIRAAI

ROW SPACING : 60 cm

PLANTED : 11 JULY (IN SHALLOW FURROW)

RAINFALL : 572 mm

SOURCE : ANNUAL REPORT ON ADAPTIVE AGRONOMIC RESEARCH TRIAL CONDUCTED AT AGADI, SAMSAM AND EL FUDA BY SENIOR AGRONOMIST AND MFC STAFF. MECHANIZED FARMING CORPORATION 1980/81.

TABLE 66

CULTURAL PRACTICES

PLANT SPACING

COWPEAS

EL FUDA

1981/82

WITHIN ROW SPACING	BEAN YIELD	HAY YIELD	PLANT POPULATION	BEAN YIELD PER PLANT
cm	kg/ha	kg/ha	(000)/ha	g
30	500	1464	33	15.0
20	416	1873	52	8.0
15	426	1873	57	7.5
SE±	40	193		---
F	NS	NS	74.33**	---
C.V.%	19	22	6	---

CULTIVAR : LOCAL

BETWEEN ROW SPACING : 60 cm

SOWN : 20 JULY

MAY-OCT. RAINFALL : 634 mm

SOURCE : ANNUAL REPORT ON ADAPTIVE AGRONOMIC RESEARCH TRIALS CONDUCTED AT AGADI, SAMSAM AND EL FUDA BY SENIOR AGRONOMIST AND MFC STAFF. MECHANIZED FARMING CORPORATION 1981/82.

TABLE 67

CULTURAL PRACTICES

PLANT SPACING

MILLET

EL FUDA

1981/82

INTER-ROW SPACING	GRAIN YIELD	PLANT POPULATION	NO.OF HEADS PER UNIT AREA	PERCENT OF PLANTS WITH HEADS	GRAIN PER HEAD
cm	kg/ha	(000)/ha	no./ha	%	g
30	438	45	68	152	6.5
20	505	69	76	110	6.6
10	333	141	83	60	3.9
SE±	67	0.5	7.9	1.3	---
F	NS	16430**	NS	13.05**	---
CV%	31	1	21	24	---

CULTIVAR : LOCAL

INTER-ROW SPACING : 60 cm

PLANTED : 7 JULY

RAINFALL : MAY - OCT = 634 mm

SOURCE : ANNUAL REPORT ON ADAPTIVE AGRONOMIC RESEARCH TRIALS CONDUCTED AT AGADI, SAMSAM AND EL FUDA BY SENIOR AGRONOMIST AND MFC STAFF. MECHANIZED FARMING CORPORATION 1981/82.

TABLE 68

CULTURAL PRACTICES

PLANT SPACING

GROUNDNUTS

EL FUDA

1981/82

INTER-ROW SPACING	POD YIELD	PLANT POPULATION	POD YIELD PER PLANT	SHELLING OUT-TURN
cm	kg/ha	(000)/ha	g	%
30	735	71	10.3	75
20	795	105	7.6	76
15	1054	195	5.4	77
SE±	40	8	----	0.5
F	17.29**	63.60**	----	5.94**
C.V.%	9	13	----	1

CULTIVAR : BARBERTON

INTER-ROW SPACING : 60 cm

SOWN : 5 JULY

RAINFALL MAY-OCT. : 634 mm

SIGNIFICANCE : 5%* , 1%**

SOURCE : ANNUAL REPORT ON ADAPTIVE AGRONOMIC RESEARCH TRIALS CONDUCTED AT AGADI, SAMSAM AND EL FUDA BY SENIOR AGRONOMIST AND MFC STAFF, MECHANIZED FARMING CORPORATION 1981/82.

TABLE 69

CULTURAL PRACTICES

SEED RATE

MILLET

EL FUDA

1980/81

SEED RATE	YIELD	PLANT STAND
kg/ha	kg/ha	no./ha
1.2	593	133
2.4	897	158
3.6	1066	225
SE ±	90	---
C.V.%	50	---

CULTIVAR: LOCAL VARIETY

SEED TREATMENT: ALDREX-T

SOWN BY WIDE LEVEL DISC 10 JULY

YIELD DIFFERENCES SIGNIFICANT AT 5% LEVEL

RAINFALL = 572 mm

SOURCE: ANNUAL REPORT ON ADAPTIVE AGRONOMIC RESEARCH TRIALS CONDUCTED AT AGADI, SAMSAM AND EL FUDA BY SENIOR AGRONOMIST AND MFC STAFF 1980/81.

TABLE 70

CULTURAL PRACTICES

SEED RATE

SORGHUM

EL FUDA

1981/82

SEED RATE	YIELD	PLANT POPULATION	HARVESTED HEADS	AVERAGE GRAIN/HEAD	NO. OF PLANTS WITH HEADS
kg/ha	kg/ha	(000)/ha	(000)/ha	g	&
2.4	471	48	40	11.6	85
3.6	395	81	57	6.9	71
7.1	252	86	40	6.2	47
SE±	57	7.6	5.5	----	4.6
F	NS	6.98*	NS	----	15.45**
C.V.%	30	22	24	----	14

CULTIVAR : GADAM EL HAMAM 47

MACHINE SOWN : 9 JULY

SIGNIFICANCE LEVELS : *5% , **1%.

RAINFALL MAY-OCT. = 634 mm

SOURCE : ANNUAL REPORT ON ADAPTIVE AGRONOMIC RESEARCH TRIALS CONDUCTED AT AGADI, SAMSAM AND EL FUDA BY SENIOR AGRONOMIST AND MFC STAFF, 1981/82.

TABLE 71

CULTURAL PRACTICES
POPULATION DENSITY
SORGHUM & MILLET
BANJADEED & KABA, EL OBEID
1983

POPULATION DENSITY	YIELD SORGHUM [1	YIELD MILLET [2
(000)/ha	-kg/ha	
12	182	959
24	320	919
36	265	983
48	249	932

[1 P898012 AT BANJADEED

[2 UGANDI AT KABA

ANNUAL RAINFALL : KABA = 382 mm
: BANJADEED NOT AVAILABLE

SOURCE: 3RD PROGRESS REPORT
KSU/SUDAN INTSORMIL PROJECT
SEED SOURCE ARC/ICRISAT CROP PROGRAM

TABLE 72

CULTURAL PRACTICES
PLANT SPACING
WATERMELON
EL OBEID
1983/84

INTER-ROW SPACING	INTRA-ROW SPACING (m) 1.0	1.5	2.0	MEAN
m.	YIELD			
	- - - - t/ha - - - -			
2	10.0	5.2	6.0	7.1
3	7.7	4.4	5.0	5.7
MEAN	8.8	4.8	5.5	6.4
	NO. OF FRUIT PER HECTARE			
	- - - - no/ha - - - - -			
2	3700	1850	1760	2440
3	2590	1480	1850	1970
MEAN	3150	1670	1800	2210

PLANTED : 29 JULY 83
CULTIVAR : BALADI
RAINFALL : 339 mm

STANDARD ERRORS	kg/ha	n/ha
INTER-ROWS	0.75	295
INTRA-ROWS	0.92	360

SOURCE : REPORT ON THE HORTICULTURAL RESEARCH ACTIVITIES, EL OBEID RESEARCH STATION, 1983/84 (BY OSMAN ADAM OSMAN).

TABLE 73

CULTURAL PRACTICES
WEEDING/SORGHUM
KADUGLI
1978/79 & 1979/80

WEEDING TIMES DAYS AFTER EMERGENCE 7	14	28	YIELD 1978/79	1979/80
			kg/ha	
X			1325	2471
	X		----	2582
		X	242	2246
X	X		1389	2731
X		X	1211	2856
	X	X	716	2296
X	X	X	1416	2175
WEED	FREE		1723	2253

ANNUAL RAINFALL: 1978 = 742 mm
: 1979 = 397 mm

SOURCE : KADUGLI STATION RECORDS

TABLE 74

CULTURAL PRACTICES
LABOR SAVING COST / BENEFIT ANALYSIS
WEED CONTROL BY PLOWING AND/OR HERBICIDE APPLICATION
MILLET
NYERTETE, JEBEL MARRA
1982

CULTIVATION	HERBICIDE	EXTRA COSTS CULTV.	EXTRA COSTS HERBICIDE	EXTRA COSTS CHEMICAL SPRAYING	TOTAL COSTS	LABOR NET SAVED (BENEFITS)	BENEFITS	BENEFIT / COST
		LS						
ZERO	ZERO	0	0	0	0	0	0	-
ZERO	SORGOPRIM	0	35	5	40	42	2	1.05
ZERO	GESAPRIM	0	7	5	12	33	21	2.75
PLOW	ZERO	45	0	0	45	61	16	1.36
PLOW	SORGOPRIM	45	35	5	85	66	-19	0.78
PLOW	GESAPRIM	45	7	5	57	68	11	1.19

ANNUAL RAINFALL = 443 mm

SOURCE: JMRDP ANNUAL REPORT ANNEX I 1982/83

TABLE 75

CULTURAL PRACTICES
PLOWING
PHOSPHOROUS FERTILIZER
MILLET
DIMSU, S. DARFUR
1983

	YIELD		
TSP	CULTIVATION		
FERTILIZER RATE	NONE	PLOWING[1]	AVERAGE
kg/ha OF P_2O_5	- - - - - - - kg/ha - - - - - - - - -		
0	207	246	236
23	403	503	478
AVERAGE	305	375	357

[1 AVERAGE OF 3 TREATMENTS

ANNUAL RAINFALL = 358 mm

SOURCE: REPORT ON TRIALS CARRIED OUT AT THREE EXPERIMENTAL SITES IN SOUTH DARFUR 1983 TRIAL RESULTS WSDC / HTS FEBRUARY 1984

TABLE 76

CULTURAL PRACTICES
PLOWING
SORGHUM
JEBEL MARRA
1983

TREATMENT	YIELD
	kg/ha
MOULDBOARD PLOWING	2793
NOT PLOWED	2134

RESULTS ARE SIGNIFICANT AT 5% LEVEL
SOURCE: JMRDP 1984 AG. REVIEW

TABLE 77

CULTURAL PRACTICES
COST: BENEFIT ANALYSIS OF
PLOWING/NITROGEN/NAFAASHA CONTROL/TIME OF WEEDING
MILLET
NYERTETE
1983

	BENEFITS				NET BENEFIT	BENEFIT
	EXTRA YIELD	EXTRA RETURNS	LABOR SAVED IN WEEDING	COST OF FACTOR(S)	(WITH LABOR SAVED)	COST(WITH LABOR SAVED)
	kg/ha	- - - - - - - - - - - - - - -		LS	- - - - - - - - - - - - - - - - - - - -	
PLOWING	+54	+27.0	+60.5	-50.0	-23.0(+37.5)	.54(1.75)
NITROGEN (120 kg/ha UREA)	+45	+22.5	-----	-120.0	-97.5	.19
PLOWING + N	+453	+226.5	+60.5	-170.0	+56.5(+117.0)	1.3(1.69)
NAFAASHA* CONTROL						
WITH LATE WEEDING	-132	-66.0	----	-20.0	-86.0	-3.3
WITH EARLY WEEDING	+225	+112.5	----	-20.0	+92.5	5.6

* NAFAASHA IS A WORM WHICH ATTACKS MILLET HEADS AND IS A SERIOUS, YIELD REDUCING, PEST.

CULTIVAR: BAYUUDA

RAINFALL: 470 mm

SOURCE : JMRDP 1983/84 ANNUAL REPORT ANNEX I

TABLE 78

CULTURAL PRACTICES

GROUNDNUTS INTERCROPPED WITH MILLET OR SESAME

EL OBEID

1983

CROPPING PATTERN	YIELD		
	GROUNDNUTS	MILLET	SESAME
	- - - - - - - - -	kg/ha	- - - - - - - - - - -
PURE STAND	362	117	336
GROUNDNUT/MILLET [1	607	131	---
GROUNDNUT/SESAME [1	559	---	178

[1 AVERAGE OF 4 TREATMENTS

NOTE: GROUNDNUT & MILLET YIELDS IMPROVED BY INTERCROPPING.

PERSONAL OBSERVATION BY JJR: PLOTS OF GROUNDNUT INTERCROPPED WITH MILLET HAD LESS SOIL REMOVED BY WIND THAN GROUNDNUTS PLANTED ALONE.

ANNUAL RAINFALL: 339 mm

SOURCE: WSARP EL OBEID STATION REPORT 1983

TABLE 79

CULTURAL PRACTICES
COTTON/CROP ROTATION
EL AFEIN, (KADUGLI)
1983

PREVIOUS CROP	COTTON YIELD
	kg/ha
SESAME	590
FALLOW	180

JUNE - SEPT. RAINFALL = 448 mm

SOURCE: gtz 1984 REPORT

TABLE 80

CULTURAL PRACTICES
CROP ROTATION
SORGHUM
EL AFEIN, (KADUGLI)
1983

PREVIOUS CROPS 1981	1982	SORGHUM YIELD 1983*	(RANK)
		kg/ha	
COTTON	COWPEA	2500	(1)
FALLOW	COWPEA	1940	(2)
COTTON	SOYBEAN	1790	(3)
SESAME	COWPEA	1730	(4)
SOYBEAN	COWPEA	1550	(5)
COTTON	GUAR	1530	(6)
COWPEA	COWPEA	1520	(7)
FALLOW	GUAR	1510	(8)
SORGHUM	COWPEA	1510	(9)
SESAME	SOYBEAN	1400	(10)
TRIAL AVERAGE (36 TREATMENTS)		1260	

AVE. YIELD OF 1983 SORGHUM CROP ON FIELDS PLANTED TO COTTON IN 1981 = 1540 kg/h.
" " " " " " " " " " COWPEA " " = 1310 "
" " " " " " " " " " FALLOW " " = 1250 "
AVE. YIELD OF 1983 SORGHUM CROP ON FIELDS PLANTED TO COWPEA " 1982 = 1790 "
" " " " " " " " " " SOYBEAN" " = 1320 "
" " " " " " " " " " GUAR " " = 1230 "

JUNE - SEPT. RAINFALL (mm) 1983 = 448 mm 30 YR. AVERAGE = 557 mm

* DATA ROUNDED OFF TO NEAREST 10 kg.

SOURCE: "TABLE 16 IN INVESTIGATIONS ON IMPROVEMENT OF PLANT FRODUCTION ON VERTISOL SOILS IN NUBA MOUNTAINS REGION" 1984 GTZ.

JJR 18 AUG 84

TABLE 81

CULTURAL PRACTICES
SORGHUM/CROP ROTATION
EL AFEIN, (KADUGLI)
1983

1981	1982	1983	DEPRESSION OF 1983 SORGHUM YIELD RELATIVE TO TRIAL AVE.	YIELD
SORGHUM	COTTON	SORGHUM	-40%	(745) kg/ha
FALLOW	SORGHUM	SORGHUM	-40%	(764) "
COTTON	SORGHUM	SORGHUM	-25%	(1051) "
			TRIAL AVERAGE	(1263)

JUNE - SEPT. RAINFALL = 448 mm

SOURCE : gtz REPORT 1984

TABLE 82

ON-FARM TRIAL
IMPROVED VARIETIES OF SORGHUM
JEBEL MARRA
1982

CULTIVAR(S)	YIELD
	kg/ha
FARMERS LINE(S)	2351
GADEM EL HAMMAN	2024
DABAR	1894
UM BENEIN	1291

SOURCE: 1982-83 JMRDP ANNUAL REPORT ANNEX I

TABLE 83

ON-FARM TRIALS
SORGHUM CULTIVARS & CULTURAL PRACTICES
KADUGLI
1983

SORGHUM CULTIVAR(S)	CULTURAL PRACTICES	YIELD FARMERS 1	2	3	4	5	6	AVERAGE OF FARMERS 2, 4 & 5.
LOCAL	TRADITIONAL	-	288	-	367	362	-	339
LOCAL	IMPROVED [2	719	283	-	438	0	-	240
INTRODUCED [1	IMPROVED [2	2059	840	571	476	424	212	580

[1 GADEM EL HAMAM

[2 SEED DRESSING, HIGH POPULATION, GOOD WEEDING PRACTICES.

SOURCE: 1983 KADUGLI STATION WSARP ANNUAL AGRONOMY REPORT.

TABLE 84

ON-FARM TRIALS

SORGHUM & MILLET PLOTS

EL OBEID

1983

RATING CROP CONDITION	MID-AUGUST EVALUATION	END OF SEASON EVALUATION
EXCELLENT	III	
VERY GOOD	IIII	
GOOD	III	I
FAIR		III
POOR	II	
VERY POOR		~~IIII~~ II

SAMPLE SIZE: 11 FARMS

MAJOR PRODUCTION CONSTRAINTS	NO. OF CASES*
DROUGHT	~~IIII~~ ~~IIII~~
STRIGA	III
WIND	II
GRASSHOPPERS	II
BIRDS	I
SINTA	I

SAMPLE SIZE: 11 FARMS

* SOME FARMERS LISTED MORE THAN 1 CONSTRAINT

SEED SOURCES: LOCAL/ARC/ICRISAT

SOURCE : 3RD PROGRESS REPORT
KSU/SUDAN INTSORMIL PROJECT

TABLE 85

ON-FARM TRIAL
IN-ROW SPACING/NITROGEN
SWEET PEPPERS
BANJADEED
1983/84

IN-ROW SPACING	YIELD NITROGEN LEVEL (kg/ha) 0	40	80	120	160	MEAN
cm	t/ha					
30	17.2	18.3	19.7	17.8	21.4	18.9
45	17.5	19.9	18.1	18.9	16.2	18.1
60	13.2	15.5	17.6	13.3	16.1	15.1
MEAN	16.0	17.9	18.5	16.7	17.9	17.4

CULTIVAR : YOLO WONDER
PLANTED : 5 OCT 83
TRANSPLANTED : 1 DEC 83

BANJADEED RAINFALL DURING TRIAL = 0
(TRIAL IRRIGATED)

S.E.(IN-ROW MEANS) = 0.59
S.E.(N MEANS) = 0.77

SOURCE: REPORT ON THE HORTICULTURAL RESEARCH ACTIVITIES
EL OBEID RESEARCH STATION 1983-84 (BY OSMAN ADAM OSMAN)

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3. Labor Proportions by Activity for Sorghum at Tabaldia, S. Darfur 1983.

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5. Weed control in Millet, Nyertete, 1982.

6. Final Grain Yield of Millet and Mid-Season Weed Density, Nyertete, 1982.

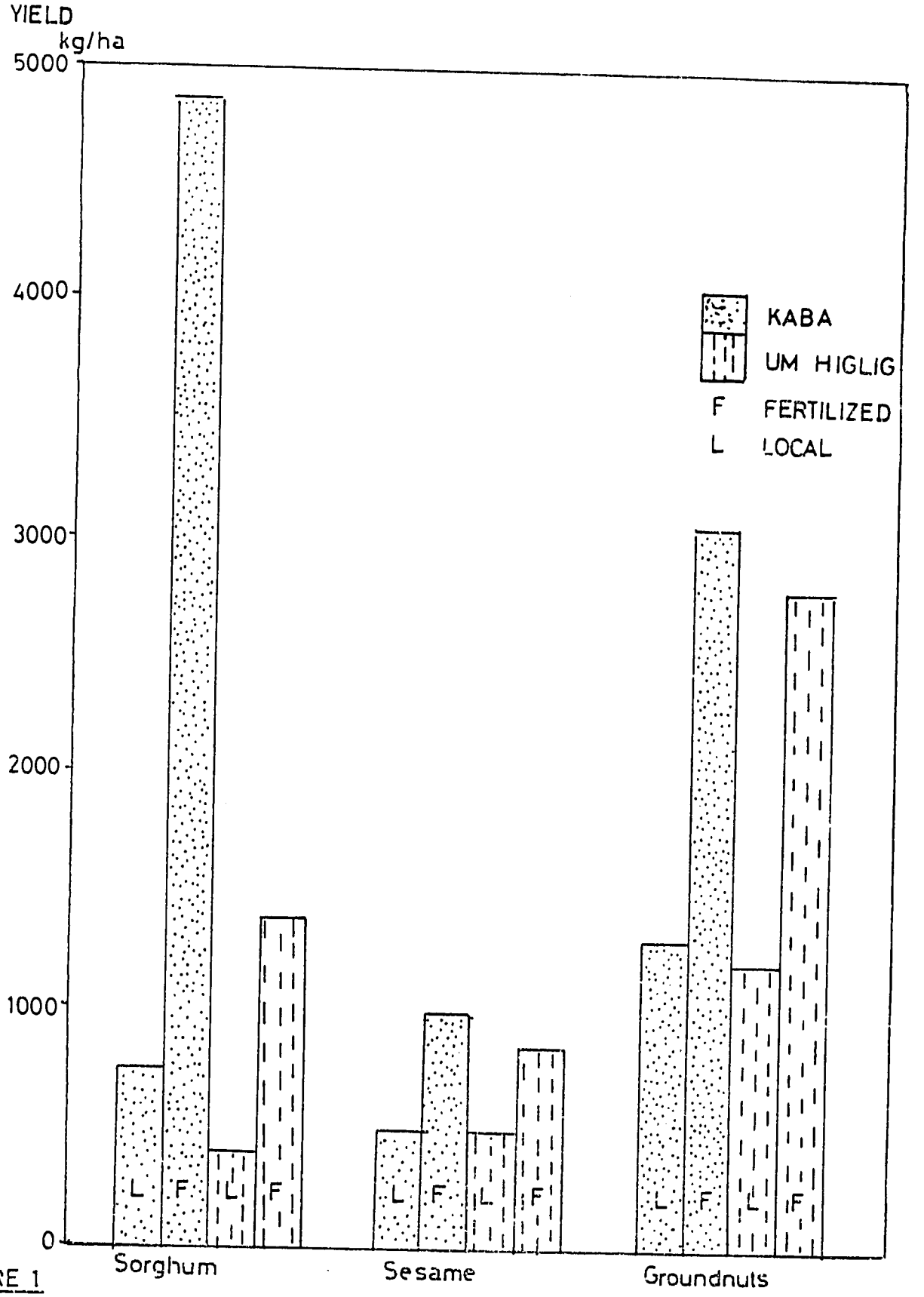


FIGURE 1

YIELDS OF SORGHUM, SESAME AND GROUNDNUTS OBTAINED FROM FERTILIZERS TRIALS COMPARED WITH MAXIMUM YIELDS OF LOCAL FARMERS

Source: AGRONOMY INVESTICATIONS, DOXIADIS ASSOCIATES, PUBLICATION, DOX-SU A-35, 1965

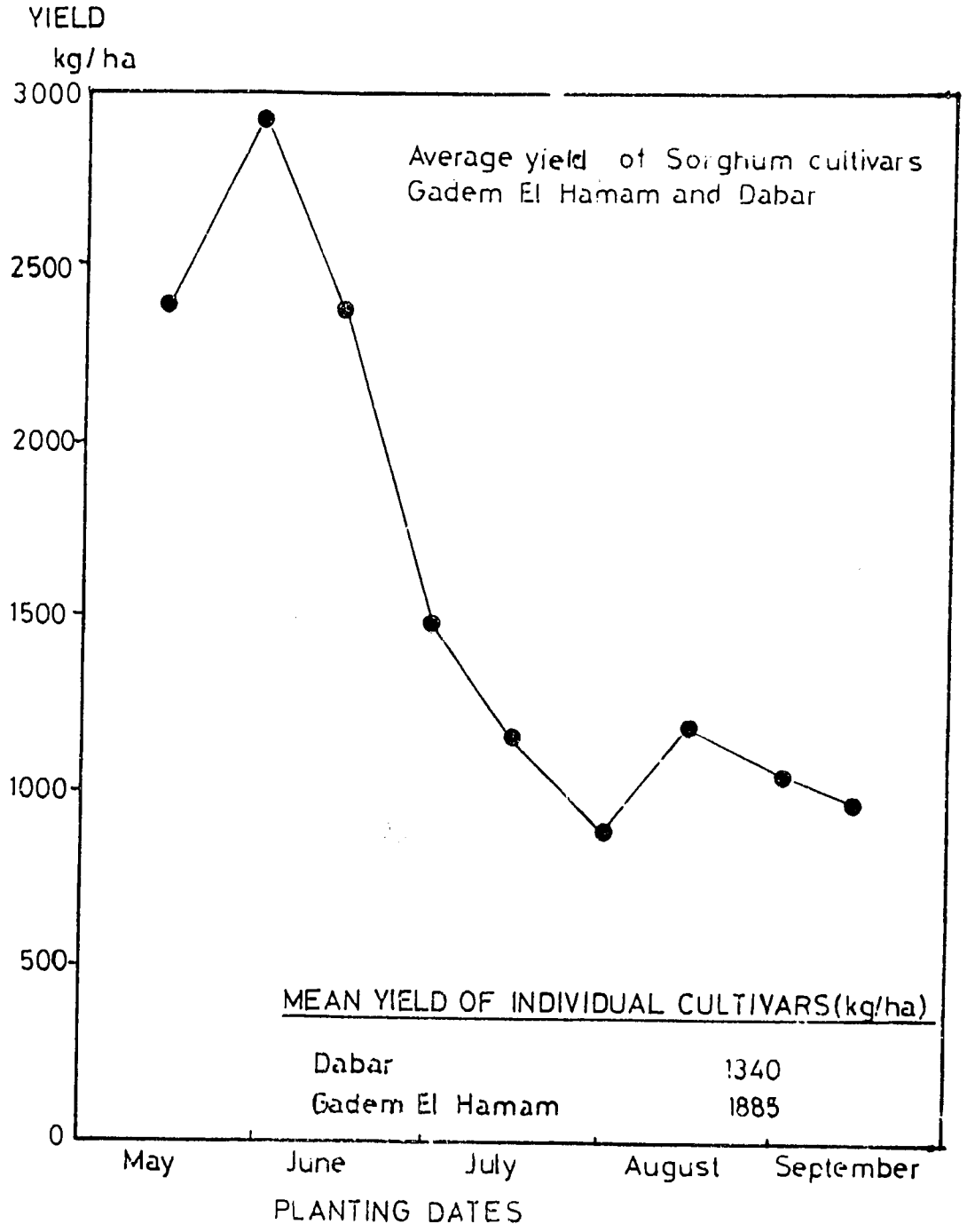


FIGURE 2

CROP RESPONSE TO CULTURAL PRACTICES

SORGHUM/PLANTING DATE, KADUGLI 1979/80

Source: KADUGLI STATION RECORDS

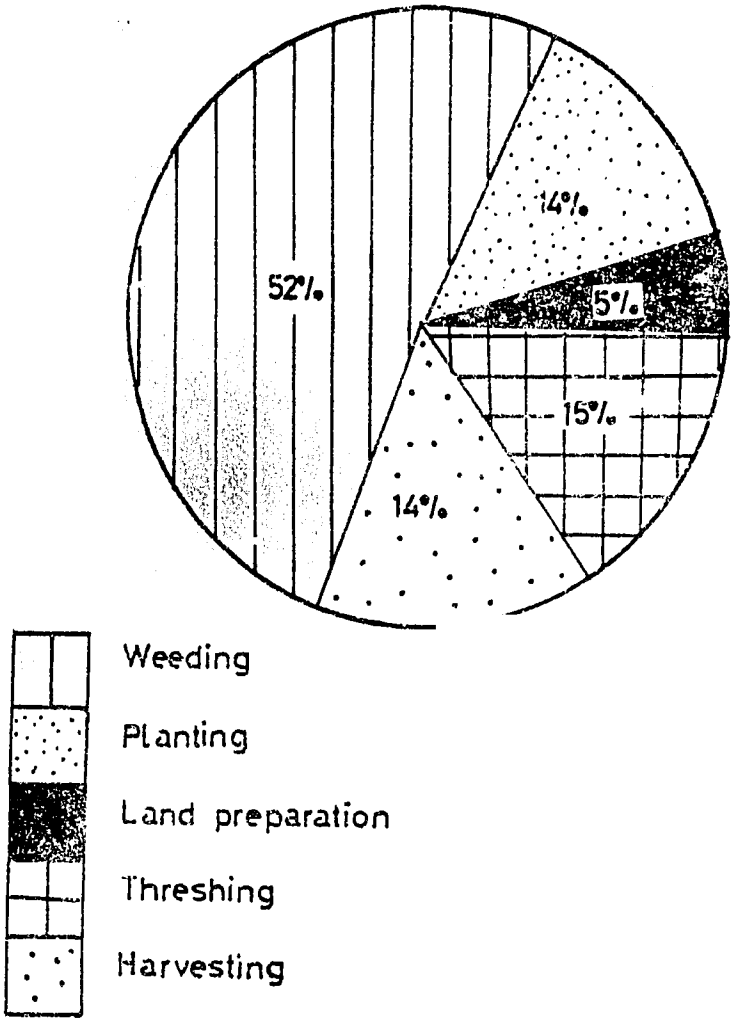
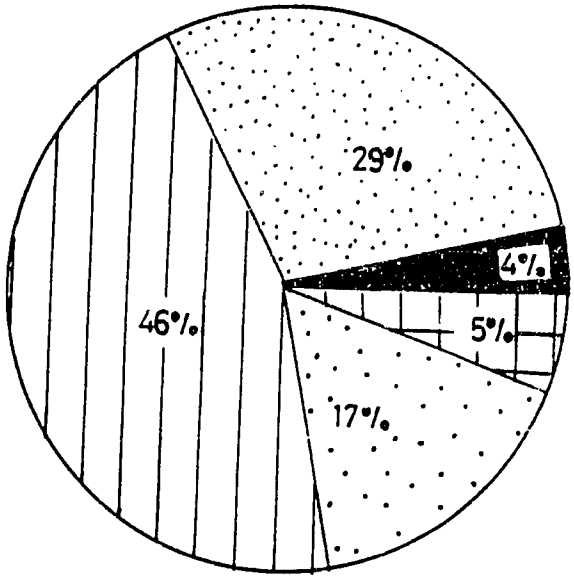


FIGURE 3

LABOR PROPORTIONS BY ACTIVITY FOR SORGHUM AT TABALDIA, S. DARFUR

Source: JMRDP ANNUAL REPORT 1983-84 ANNEX II SEP 84 HTS



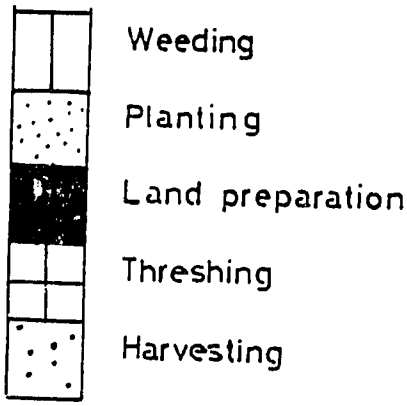


FIGURE 4

LABOR PROPORTIONS BY ACTIVITY FOR MILLET AT BARDANI, S. DARFUR

Source: JMRDF ANNUAL REPORT 1983-84 ANNEX II SEP 84 HTS

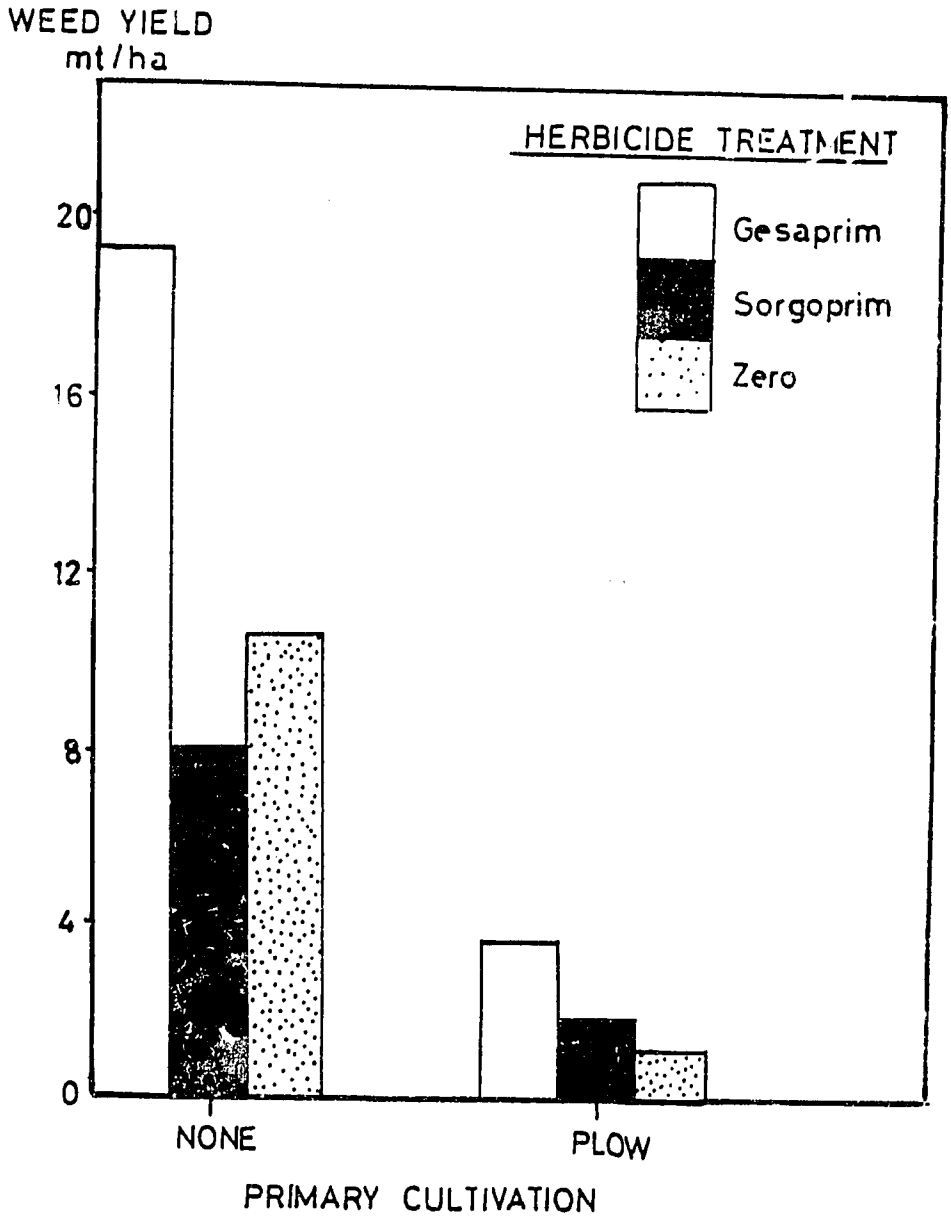


FIGURE 5

WEED CONTROL IN MILLET, NYERTETE 1982

Source: 1982-83 JMRDP ANNUAL REPORT ANNEX I

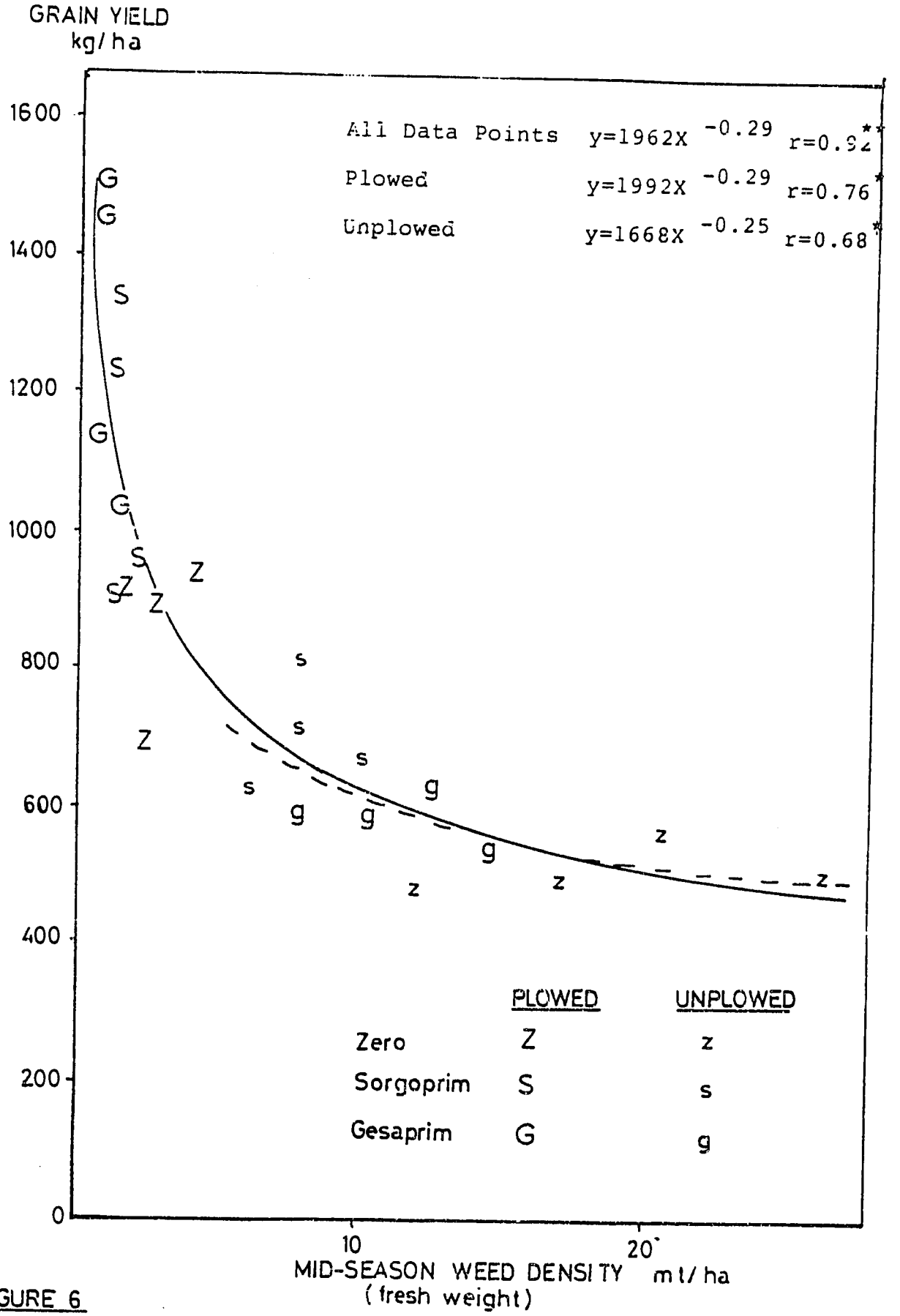


FIGURE 6

FINAL GRAIN YIELD OF MILLET AND MID SEASON WEED DENSITY

NYERTETE, 1982

Source: 1982-83 JMRDP ANNUAL REPORT ANNEX I

R E F E R E N C E S

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36. Report on the Horticultural Research Activities, El Obeid Research Station, 1983-84 (By Osman Adam Osman).

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APPENDIX

Excerpts from the following reports or notes are appended for the reasons indicated:

1. Report of Pilot Scheme at El Afein Kadugli by Dr. J.R. Burford, Principal Soil Scientist, Farming Systems Program, ICRISAT (Reference No. 12).

   This report details the problems of crop production on the cracking clay vertisols in southern Kordofan and presents several alternative plans for improving yields.

2. Summary of Main finding for Sorghum and Millet from 1981 to 1984 in Jebel Marra Rural Development Project. Excerpt from JMRDP 1983-84 Annual Report Annex I HTS September 1984 (Reference No. 24).

3. Sudan fertilizer nomenclature and equivalencies for use in comparing different ways in which fertilizer application rates are expressed.

4. Location, elevation and soil type of experimental sites.

REPORT ON PILOT SCHEME AT EL AFEIN, KADUGLI

DR. J.R. BURFORD

Principal Soil Scientist
Farming Systems Research Program
ICRISAT

1. The general term of reference for this consultancy were to compare the agricultural environments at Hyderabad and Kadugli, and thus to suggest for the existing GTZ "Pilot Project" at Kadugli:

   (a) Components of ICRISAT's (Farming Systems) technology for deep Vertisols which could be incorporated into the existing project (and the ease of implementation, or otherwise).

   (b) A long-term strategy for research into, and implementation of improved Farming Systems for the region.

2. PRESENT PROJECT consists of:

   (i) Implementation of "improved" practices in a mechanized scheme. The major "improved inputs: are mechanized land preparation, and use of improved cultivars. The scheme consists of ca 300 farmers on ca 3000 feddans (acres) of cracking clay soils. The present cropping sequence of cotton - cowpea - sorghum - sesame is managed by growing these crops in belts; land within these belts is allocated to farmers each year, on the basis of number of effective working members in each household.

   (ii) Research, which was commenced to provide some of the basic information not available from other sources.

3. BACKGROUND:

Several feasibility studies have been made previously e.g., Agar Hydro-Technique (for GTZ), Huntings Technical Services (for ODA). From a very large area (600,000 ha), the AHT survey covered a very large study area (200,000 ha), a lesser proposed development area (73,500 ha) and a smaller Pilot Project (1500-2000 ha) the site for which was eventually located outside the originally-selected Study and Development areas. The area of the Pilot Project was also smaller (3000 acres) than originally proposed. There have been considerable changes in the financing and purpose of the scheme since its original initiation.

4. COMPARISON OF ENVIRONMENTS:

The environment at Kadugli is much harsher than that at Hyderabad; the mean total rainfall is slightly lower at Kadugli (725mm vs. 800mm at ICRISAT HQ), but the major difference is that rainfall at Hyderabad is relatively assured from the commencement of the rains, whereas at Kadugli it is uncertain at first and gradually becomes more reliable as the rainy season progresses. Rainfall tends to cease suddenly at the end of the season at Kadugli, but taper off erratically at Hyderabad. Temperatures and evapotranspiration at Kadugli are generally higher than at Hyderabad; but, more important is the fact that - at Kadugli - the DERET season, occurring immediately after the end of the KHAREEF (rainy) season, is a period in which the temperature and evaporation are much

higher than in Hyderabad. These two features might hinder the immediate successful incorporation of two successful components of ICRISAT's improved Farming Systems for deep Vertisols:

(i) Dry-seeding of crops just before the beginning of the rainy season.

(ii) Prolonged cropping for several months beyond the end of the rainy season, with crops being supported entirely on stores soil moisture.

5. SOILS:

The soils are similar at both places in that they are cracking clays with a good capacity to store moisture. Further comparisons are limited by lack of detailed characterization of soils in the Southern Sudan, but indirect evidence indicates that these may have a lower water holding capacity.

6. CROPPING SYSTEMS:

The farmers in ICRISAT's On-Farm Verification Trials are given options (admittedly guided) on the crops to be grown in each year. But, at Kadugli, in the GTZ scheme, they are directed to a fixed rotation, this being cotton - Vigna (cowpea) - sorghum - sesame. This rotation allows no farmer innovation, but - much more important - this rotation has been chosen without the background research data proving that this system is viable for maintaining long-term productivity in the area. In their own traditional system, farmers at present grow mainly sorghum and some sesame (3:1), as either sole crops or

intercropped with other crops (okra, cowpea, etc.); the land is cropped for about 4 years than allowed to rest under a grass fallow for about 4 years.

7. SOCIOECONOMIC FACTORS:

Although areas of arable land per capita are larger than India, Southern Kordofan has a relatively high population density (1 per 6 ha) and farm size allocated on the GTZ Pilot Scheme is 7 acres per household of 3 active field workers. Areas per worker are therefore not as large as thought prior to my visit. Nevertheless, the shortage of labor is particularly acute at weeding-time, and is obviously a major constraint in this system. Other research has indicated that a 7-day delay in weeding can halve eventual crop yields.

One of the contributing factors to the labor shortage is the outward migration of working males AT other provinces in the Sudan particularly to the Khartoum area. In the 15-29 age group, the ratio of males:females is 1:2. This appears to be the result of the current standard of living; in Kordofan the per capita income is the second lowest in Sudan (Darfur - ajoining to the west, has the lowest average income).

Thus, the shortage of labor for weeding appears to be a result not of too large an area of land per person, but lack of productivity to attract young males to remain in the home area.

8. FARMING SYSTEMS CONCEPTS:

The present approach adopted in the scheme omits the many steps adopted by ICRISAT in its development of an improved Farming Systems; these steps are:

Base-data analysis
Component (or disciplinary) research
Multidisciplinary research
Operational Research
On-Farm Verification Trials
Implementation Schemes

Basically, the present scheme has jumped almost directly from Base Data Analysis to an Implementation Scheme without going through the intermediate FS research and development steps; there had been relatively little component research conducted elsewhere or on the present scheme. The assumption that background research had already been conducted in S. Kordofan, or elsewhere, is not correct. For example, the present scheme has been directed to adopt:

(i) a fixed rotation, without adequate research to indicate whether this can maintain fertility in the broader sense (i.e. prevent serious build up of weeds, or maintain an adequate nutrient status).

(ii) deep cultivation without adequate evidence in favor of this, and in the face of a fair body of resistance from both scientific and farmer communities.

9. ACHIEVEMENTS OF THE PRESENT SCHEME:

The scheme has achieved quite a lot in the past 3 years. It is now completing the commissioning of good office, maintenance, and housing facilities at its own base. It is establishing rapport with the 300 farmers in the scheme. Although the average farmer's yield in the scheme is not better than the traditional farmer's yields outside the

scheme, such a result is similar to those obtained in many other such schemes.

Further, I understand that the best farmer's cotton yields (3 1/2 - 4 small kantars per feddan) were the highest of any scheme in the area; also we should remember that 10% of the farmers in the scheme obtained sorghum yields (1400 kg/ha) that were more than double the average yield (700 kg/ha) for this and other schemes in the Nuba Mountains.

Finally, by observation and collection of ancillary data, the present staff are becoming more acquainted with the real problems of the farmers; and, by analysis of yield versus environment associations, they will be able to identify at least some of the major factors involved in causing particularly low and particularly high yields.

10. FUTURE STRATEGIES:

10.1 Problem Definitions

The project was founded on the assumption that deep cultivation could replace the harig-shifting cultivation system as a means for preparation of soil for cropping. There is the unstated assumption that the assistance with agronomic management by project personnel would provide the essential feature that would life productivity above that of other small-holder mechanized schemes.

There are, however, many identifiable problems which need to be researched before we can recommend viable systems that assure improved productivity. The major problems quoted in other previous reviews still have not been adequately solved:

- Establishment problems (due to unreliability of early rains) leading to late sowing and poor plant stands
- Weed control
- Rotations - almost a complete lack of knowledge

11. FUTURE STRATEGIES: Discussion

The agricultural environment at Kadugli is sufficiently different to that at our Hyderabad location that immediate transfer of the present ICRISAT Farming Systems technology for deep vertisols is not possible. The major limitation is the shorter rainfall season, thus apparently preventing double cropping, but there are other major differences.

The lack of a large body of research data for the area such as led to the development of ICRISAT's Technology (10 years of our own research plus a large body of existing results from Indian institutions), is perhaps the next constraint; to attempt to minimize the effect of this we can pursue one of two major options:

(i) Attempt to identify other areas in the Sudan with more assured rainfall, and soils more similar to those at ICRISAT.

(ii) Attempt to adapt ICRISAT's present findings to the present Nuba Mountain situation, by conducting substantial further research (of the order of several years).

Option (i) could not be pursued further during my stay, because travel over any distance during the wet season was not possible. Sites with higher rainfall, and soils more similar to those at ICRISAT, are likely to be found further south in the Sudan; but, the matching of such environments will need to be done carefully.

Option (ii) would require adoption of the research approaches advocated by ICRISAT, and described recently in a formal publication. But a substantial commitment for several years (e.g. 5-7 years) would be needed, even with the advantage of assistance in the form of methodologies and prior research finding at ICRISAT. This research would follow the pattern outlined earlier - (more detailed) base data analyses, substantial research, On-Farm Verification (OFV). There should be a strong involvement of Sudanese Scientists, together with experienced ICRISAT Farming Systems scientists.

In discussions with GTZ staff at both the policy and implementation level, I was informed that the above thorough research approach was not acceptable - mainly because of the need for results within the next 3 years. I disagree with such excessive haste, because there are many other development/implementation projects in which the folly of excessive haste has caused failure, embarrassment, and lost reputations; nevertheless, to cater for the request for

suggestions for the next 3 years, I have given two options in the next section.

12. FUTURE STRATEGIES: Short Term - the options

The terms of reference requested a statement of the components of ICRISAT's deep vertisol technology that could be incorporated into the present project without altering the existing structure and financing. the simple statement is that there are virtually no innovations that can be immediately introduced - primarily because this is an implementation scheme and not an Evaluation or Pilot Project. The size (1300 ha) is very much larger than we would recommend (usually 10-30 ha), and any errors in prediction (which would be likely in view of the lack of pre-implementation testing) would be very costly in terms of loss of farmer confidence.

Because our policy is to test recommendation (themselves based on research) on OFV areas - small in area - prior to implementation, a change in structure of the activities of the project is recommended. this assumes that the project continues for another 3 years, as indicated. However, because of the request to make suggestions without change in structure two options will be given - with change in structure, and without change in structure. Because we must assume inadequate background research will have been conducted, no guarantees can be given for either approach.

12.1 Without change in project structure

(i) Extend the present rotation to 5 years, to provide flexibility in future in view of the lack of knowledge of rotations, the probability that the present rotation may not maintain soil fertility, and the need for semi-permanent land allocation, after which an increase in length of rotation (and reduction in each farmer's area) would be difficult.

(ii) Improve the existing crop and sowing procedures

(a) Cowpea production has so far been relatively uneconomic; therefore, grow this crop as an intercrop amongst the sorghum and use the existing "cowpea year" for a more efficient N-fixing legume (Sesbania?)

(b) Attempt earlier sowing of sorghum, using a longer season cultivar than Gadem El Hamam; if this fails, then recultivate and resow using shorter-season cultivars (e.g. Dabar, Gadem El Hamam, or Dr. Gibiza's new Hybrid).

(c) Cultivation: Land to be sown (to sorghum or cotton) in the next season should be ploughed (disc or mouldboard) immediately after harvest or previous crop.

SUMMARY OF MAIN FINDINGS FOR SORGHUM AND MILLET FROM 1981 TO 1984, JEBEL MARRA RURAL DEVELOPMENT PROJECT

At the end of Phase 1 of the Project, it is appropriate to summarize the main findings of the work from 1981 to 1984. These indicate several ways in which sorghum and millet yields can be increased or maintained in the short-term and should form the basis of the Extension Program through the Interim Phase. It is clear that there are many areas where further adaptive research is required (particularly germplasm and animal-drawn implements), and it is now an appropriate time to redirect attention to some of the longer-term issues facing the people of the Project area, particularly tree/crop systems and small-scale irrigation. The main findings for millet and sorghum are:

1. Mouldboard ploughing gives higher yields per unit area than other cultivation treatments or zero tillage. This yield advantage is associated with soil and moisture factors (1981 Cultivation systems observation plots; 1982 Trial 1-1; 1983 Trial 1-1).

2. Ploughing also gives better control of weeds, reducing weed mass at time of first weeding by about 80 percent (1982 Trials 1-1 and 3-1).

3. Farmers appear to realize both types of benefit in that they claim higher yields per unit area and are able to cultivate larger areas when using ploughs (1981 Camel Plough Survey and subsequent Moneval data; 1983 agricultural input evaluation).

4. The locally made plough has several production faults (which are easily corrected) and several design features which could be improved (method of adjustment and mouldboard).

5. Pre-rains tined cultivation leads to poorer crop growth and increased weed competition compared with mouldboard ploughing (1981 Cultivation systems observation plots; 1982 Trial 1-1).

6. Maximum retention of rainfall and an even distribution of moisture is achieved under tied ridging; ploughing causes retention but with uneven distribution; and open ridging leads to accelerated run-off and soil erosion on piedmont ash soils. The practicality of tied ridging is nevertheless questioned in view of experience elsewhere (1983 Trial 1-5).

7. Inter-row weeding has been shown to be technically feasible using camels at crop row widths of 0.75 meters. Imported implements such as the Sine and Arara

Multiculteurs perform well but are not an appropriate technical solution in view of their cost. We need to perfect a weeder that can be built by local artisans from scrap metal or wood, can be pulled by camels or donkeys, and which costs about LS 75.00.

8. Camels are by far the most popular draught animal and they show many technical and economic advantages over other types. However, there are problems with theft and the initial purchase cost, and there is a demand from farmers for donkey-scale implements. There is little interest in oxen, although their use is known of in the area (1981 Camel Plough Survey).

9. Of the wide range of local sorghum varieties, those preferred for food (asiida and kisra) are the white-grained Fasiikh types. Maareg types are slightly less preferred, and Ferteriita types are not popular except in circumstances where early maturity is essential. White seeded types are found in all three classes and account for about 80 percent of the heads in a typical mixed stand. Colored types are more resistant to bird damage and are used principally for illicit brewing and only occasionally for asiida (1981 Germplasm survey and collection).

10. Local sorghum varieties are mostly late-maturing, but are adapted to the favorable moisture conditions of many of the alluvial soils. Even in years of below-average rainfall, highest yields are given by all but the very latest maturing lines in suitable locations. There is very little scope for selection of significantly earlier-maturing lines from within the local material, although sorghums in the Upper Valleys are generally slightly earlier than those in the Lower Valleys (1982 Trial 2-1; 1983 Trial 3-4).

11. The imported varieties Dabar and Gadem El Hamam are earlier maturing and produce acceptable yields on soils with less favorable moisture characteristics. Gadem El Hamam slightly out-yields Dabar except in the Jebel piedmont, where, in any case, millet is generally preferred; however it has some feteriita in its pedigree and is not well liked by farmers (1982 Trial 2-7).

12. The Sorghum National Yield Trial contains several lines having superior grain characteristics to Dabar and a range of maturity both earlier and later. In view of rainfall trends, obtaining sufficient seed of these for on-farm verification trials should be given top priority (1983 Trial 2-6).

13. Local millet varieties show a wide range of characteristics and maturity. There is plenty of scope for the selection of earlier maturing material for the wetter parts of the Project area, but little scope for even earlier material for the dryer parts. Northern Darfur, a potential source of early maturity, has very little grain left in it after the droughts of 1982 and 1983. Grain color does not seem to be such an important factor as in sorghum (very dark grains are not liked), and the flavor of millet asiida is often preferred to sorghum (1981 Germplasm survey and collection; 1982 Trial 2-2).

14. Imported varieties of millet, whilst complementing the maturity range of local material, fail to compete on performance. This seems to be largely related to their lesser vigor, particularly early in the season. ICRISAT's material appears to have been selected under a more favorable environment with regard to either fertility or ability to compete with weeds (1981 Trial 2-1; 1982 Trial 2-4 and 2-6, 1983 Trials 2-1 to 2-5).

15. The principal crop pests in the area are millet head-worm (nafaasha), grasshoppers and blister beetles. Others having the potential to do serious damage in certain years are armyworm and stemborers. Monkeys are occasionally serious as a local pest, and birds rarely

so. Losses to storage pests under farm conditions are minimal (1983 Crop Production Survey).

16. Loss in grain yield in millet to nafaasha can reach 40 percent. Control of the pest using cypermethrin is effective and probably justified. Poison baits should continue to be used against grasshoppers, armyworm outbreaks should be controlled locally and blister beetles should probable be controlled above certain levels. Other chemical control measures are of questionable benefit (1982 Trials 3-4, 3-5 and 3-6; 1983 Crop Protection Survey and Trial 3-6).

17. The most effective method of weed control is mouldboard ploughing. Herbicides reduce the weed mass at the time of first weeding by about 50 to 70 percent in millet and sorghum, and in groundnut they are highly effective. In terms of both cost-benefit ratio and practicality, ploughing remains the most effective method, as its use should also result in other yield gains (1982 Trials 3-1 and 3-3; 1983 Trial 3-6)

18. Yield appears to be reduced most seriously by initial incremental increases in the level of weed competition. Weeding labor input is therefore most effective when used to keep crops as clean as possible rather than in recovering already overgrown crops. There is no

"acceptable" level of weed competition in terms of cost-benefit, and if a choice must be made, best returns are given by concentrating on the already better parts of a crop, rather than in spreading effort equally over a larger area (1982 Trial 3-1).

19. Significant gains in yield have been shown from small applications of Triple Super Phosphate (18 kg/ha P205) on all soils except the piedmont ash. Responses are generally greater on sandy soils, but in general are highly cost effective. It seems to be not worth increasing phosphate application much beyond this low rate (1982 Trials 4-1 and 4-3; 1983 Trials 4-1 and 4-2).

20. Nitrogen application (55 kg/ha N) also increase grain yield and there is a significant positive interaction between nitrogen and ploughing. However, except on piedmont ash soils, nitrogen results in smaller gains that phosphate at higher cost and is therefore less justifiable (1982 Trial 4-1; 1982 Trials 1-1 and 4-1).

ITEM 3

SUDAN
FERTILIZER NOMENCLATURE
AND EQUIVALENCIES

1N = 40 pounds of nitrogen* per feddan

1N = 18.2 kg N/fd

= 43.3 kg N/ha
= 94.1 kg Urea/ha
=207.0 lbs Urea/ha
= 87.0 lbs Urea/ha
= 39.5 kg Urea/fd

* Nitrogen Content measured as total nitrogen(N)

1P = 40 pounds of phosphorus** per feddan

1P = 18.2 kg P/fd

= 43.3 kg P/ha
= 94.1 kg TSP/ha
=207.0 lbs TSP/ha
= 87.0 lbs TSP/fd
= 39.5 kg TSP/fd

** Phosphorus content measured in equivalent concentration of available Phosphoric Acid (P_2O_5)

1K = 40 pounds of Potassium*** per feddan

1K = 18.2 kg K/fd

= 43.3 kg K/ha
=190.4 lbs K_2SO_4/ha
= 86.5 kg Potassium Sulfate (K_2SO_4)/ha
= 80.0 lbs K_2SO_4/fd
= 36.4 kg K_2SO_4/fd

*** Potassium content measured in equivalent concentration of water soluble potash (K_2O)

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1 ha = 2.38 fd
1 kg = 2.2 lbs

Urea has 46% N (total nitrogen)
TSP has 46% P (P_2O_5)
K_2SO_4 has 50% K (K_2O_5).

LOCATION, ELEVATION AND SOIL TYPE OF EXPERIMENTAL SITES

EXPERIMENTAL SITE	LATITUDE NORTH	LONGITUDE EAST	ELEVATION m	SOIL TYPE	REGION *
UMM HEGLIG	13° 21'	30° 02'	---	QOZ	N.K.
GOZ ASHGAR	13° 15'	30° 26'	---	QOZ	N.K.
EL OBEID (WSARP)	13° 11'	30° 14'	570	QOZ	N.K.
KABA	13° 08'	30° 11'	565	GARDUD	N.K.
BANJADEED	12° 59'	30° 14'	---	ALLUVIAL	N.K.
WAD ASHANA	12° 58'	31° 40'	---	QOZ	N.K.
NYERTETE	12° 58'	24° 04'	1176	LOAM	S.D.
ALLOBA	12° 36'	30° 19'	---	QOZ (?)	N.K.
UMM RAKUBA	11° 19'	26° 35'	495	QOZ	S.D.
TELO	11° 04'	29° 46'	515	VERTISOL	S.K.
EL AFEIN	11° 02'	29° 48'	505	VERTISOL	S.K.
KADUGLI	11° 00'	29° 43'	500	VERTISOL	S.K.
SERAF	10° 59'	29° 44'	495	VERTISOL	S.K.
DIMSU	10° 56'	24° 35'	500	QOZ	S.D.
EL FUDA	10° 30'	27° 43'	408	QOZ	S.K.

* N.K. = NORTH KORDOFAN
S.K. = SOUTH KORDOFAN
S.D. = SOUTH DARFUR

WSARP PUBLICATIONS

Publication Number	Authors/Editor(s)	Title	Date
1	Henson/Noel	WSARP General Outline of Early Planning and Implementation Requirements	1979
2	Henson/Noel	Scope of Work for Initial WSARP Activities	1980
3	Dwyer	Consultant Report on Range-Livestock	1980
4	Henson/Noel	First Annual Report	1980
5	Henson/Noel	Summary of WSARP Planning Meeting of October-November 1980 Including Consultants Reports	1980
6	Ahmed, Dinar Geneif, Riley, Elhussein	The Horticultural Resources of the Kordofan Region of Sudan	1982
7	Henson/Noel	Second Annual Report	1981
8	Meinhart	Consultant's Report on Research Station Development	1980
9	Wilson	Consultant's Report on Livestock Production	1981
10	Bunderson	Annual Report on Range Research	1981
11	Araujo	WSARP Social Perspectives on Agricultural Research and the Southern Kordofan, Sudan: Systems of Agricultural Production Among the Nuba	1981
12	Dwyer	Consulting Report on Range Research	1981
13	Henson/Noel	Work Plan, Volume I: General Research Program and Plans	Oct. 1982
14	Henson/Noel	Work Plan, Volume II: Project History and Functional Structure	Oct. 1982

Publication Number	Authors/Editor(s)	Title	Date
15	Henson/Noel	Work Plan, Volume III: Research Plan for the Kadugli	Oct. 1982
16	McGuire	Review of Seed Program in Sudan	Oct. 1983
17	Krezdorn	Report of Visit to Sudan to Review Fruit Tree Research Program and Related Factors	Oct. 1983
18	Riley	Work Plan, Volume IV: Initial Research Proposals -- Kadugli Research Station	Aug. 1983
19	Henson/Noel	Fourth Annual Report	Aug. 1983
20	Riley	A Summary of the Darfur and Kordofan Planning Workshops	Apr. 1983
21	Nunn	Report of Visit to Sudan to Review the Organization and Development of Research Support for the WSARP Experimental Station	Feb. 1983
22	Riley	Research Program for the Kordofan Region 1984-85	May 1984
23	Cook, Runderson Fadlalla, Henson	Application of Farming Systems Research and Development to an Extensive, Sedentary Livestock Production System in Southern Kordofan, Sudan	Nov. 1983
24	Gingrich, Elseid, Kenai, Bunderson	Kadugli Agronomy Research 1983	Apr. 1984
25	Teitelbaum	Social Science Report 2/82 to 3/83	Aug. 1984
26	Arya	Gum Arabic as an Evaporation Retardant and Its Effect on Sorghum Seedling Growth and Establishment in Goz Sands	Apr. 1984
27	Obeidalla, Riley	Development of the Horticultural Potential of Kordofan Region of Sudan	Sept. 1984
28	Patrick	Adoption of a New Technology and Problems Encountered in a Nuda Mountain Village	Sept. 1984

Publication Number	Authors/Editor(s)	Title	Date
29	Cook, Bunderson Fadlalla	Range/Livestock Research Activities 1982-83	Aug. 1984
30	Patrick, Abu Sabah	The Sedentary Production System in the Nuda Mountains Area	Oct. 1984
31	Dwyer	Consulting Report: Range/Livestock Research Review and Recommendations	Oct. 1984
32	Winch	Farming Systems Research: Its Strengths and Weaknesses and the Need to Link Farm Research to Macro-Economic Circumstances	Dec. 1984
33	Henson/Noel	Fifth Annual Report	Feb 1985
34	McDonald	Hybrid Sorghum Production in the Sudan	Jan. 1985
35	Arya	Soil and Water Management and Conservation Program, North Kordofan	Feb. 1984
36	Riley	Research Program for the Kordofan Region: 1985-1986	May 1985

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