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SORGHUM IMPROVEMENT
REVIEW OF WORK AND PROGRAMMES

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SORGHUM IMPROVEMENT

SUMMARY

BREEDING

COMPOSITE POPULATIONS

Good progress has been made with sorghum improvement through recurrent selection in random-mating composite populations. The best lines from the Fast Lane population yielded around 55-60 q/ha at high fertility levels, and 25-30 q/ha at low fertility levels, comparing very favourably with the control hybrid and variety. Seven populations were tested at five sites in India, one in Thailand and one in Uganda. Several showed good stability across environments, a major objective of the programme. Individual lines produced encouraging yields, averaging 38-45 q/ha across all seven environments.

PEST RESISTANCE

In the pedigree programme, 26 good, adapted varieties from several countries were crossed with shoot-fly resistant lines (470 crosses), stem borer resistant lines (93 crosses) and midge resistant lines (466 crosses). Recurrent selection seems to be the best long-term approach for combining pest resistance with yield and grain quality. Selected lines carrying good grain quality, high yield, and either ms_3 or ms_7, were crossed to resistant sources of shoot-fly (375 crosses) stem borer (115 crosses) and midge (285 crosses) to create such a population. Crosses of the few best resistant lines were made to five advanced populations to develop "side-cars" for feeding resistances in to these populations. Genetic tests indicate that our field screening technique for shoot-fly resistance can be used effectively in S_1 and S_2 lines, but not in half-sib rows.

STRIGA

Striga is a major cause of yield loss in many places. The identification of the low stimulant production type of resistance, using seedlings in the laboratory, has now been standardised, with the help of WRO, Oxford. We have started field testing of cultivars reported as resistant, and of lines withdrawn from a Nigerian composite population of types resistant to *S. hermonthica*. We are able to test at Akola as well as Patancheru through co-operation with Punjabrao Krishi Vidyapeeth. A synthetic "strigol" analogue from Sussex University used at 5 ppm. again reduced the striga population in red soil to 15 percent of that in the control: but was completely ineffective in black soil.

INTERNATIONAL TESTING

Four trials were sent to various locations in India, Africa, S.E. Asia and S. America. Data have been returned from only some sites. On the ICRISAT site itself, we tested at both high fertility (111N: 105 P_2O_5) and low fertility (20N: $20P_2O_5$).

Some of the All India Co-ordinated Sorghum Improvement Project lines did well at several centres including W. Africa. Material of Serere, Uganda origin also did well, especially within 10^0 of the equator. These multilocation tests are very important in breeding for stability of yield.

EARLINESS WITH MOULD RESISTANCE

The pedigree programme to produce types with non-weathering, lustrous grains resistant to grain moulds in short-term sorghums involved intercrossing 30 early types (40-50 days to flower) 23 mould tolerant types, and 23 high yielding cultivars adapted to various parts of Africa and to India. A total of 2250 single, 341 double, and 175 three-way crosses were made in the kharif, but sixty percent were rejected after the rabi planting when more information on the mould resistance of the parents became available. The F_3 progenies from 2,500 selections will be screened for mould resistance in the 1976 planting. All the single and double crosses were crossed to good early steriles (ms_3 or ms_7), for composite population development, 454 good grain, short-term selections were taken from random-mating populations, and the mould resistance Nigerian Composite was random-mated and 426 steriles were selected.

Early, adapted lines were crossed to 35 parents with large glumes, to transfer the grain protection afforded by large glumes. Some 286 single, 26 double, and 25 F_2 hybrids were grown in the kharif, and the value of the large glumes will be field tested in 1976. The creation of a random mating population was also begun, deliberate sibbing being used as natural outcrossing with large glume types is probably low.

GRAIN QUALITY

The new "good grain" population for evident grain quality was still under development: types with very large grains, and also a range of "local" cultivars highly esteemed for quality were crossed with the population to create "side cars" for these characters. Segregates from RY 49 were backcrossed to RY 49, and we now have photoinsensitive derivatives which carry the wheatlike flavour of this parent type. Quality samples were sent to CFTRI for study. Progress with high lysine crosses was puzzling: inbred selections with high lysine levels for three previous generations failed to show high lysine this year: yet in every case, the protein levels were unusually high, and sometimes double the values for earlier generations. P721 was stable for these characters, but showed some pollen sterility. Populations involving both groups are being created.

GRAIN-GRASS SORGHUMS

The large number of crosses made between grain-grass types and cultivated sorghums with yield, resistance, or quality characters enabled much selection to be done, and some of the material is now in the F_5. As a group, they showed good cold tolerance in the rabi season, with little change of maturity length, and the physiologists found excellent drought endurance. Non-senescent types which ratoon easily were also identified. There is a real potential for this new plant type, which will be grown at higher plant populations than normal sorghum.

TETRAPLOID GRAIN SORGHUM

Progress was made in developing photoperiod insensitive types with better grain quality, and crosses and backcrosses were made to *halepense* types to move the excellent adaptive characteristics into the cultivated crop.

GERMPLASM

A total of 14240 accessions is now available in the ICRISAT germplasm bank. Part of the World Collection was received from Purdue, and grown alongside the corresponding cultivars here to identify mistakes and contaminations. In the rabi season, 147 new farmers types were collected in Andhra Pradesh, and 211 new accessions were received. The whole collection, other than new accessions, was evaluated for principal morphological characters, and the data are being sent to the Colorado University Taximetric laboratory to supplement the pilot catalogue. Screening for disease, pest, striga, or drought resistance was done by the appropriate scientists on 5877 entries.

ENTOMOLOGY

More than 95 percent of the flies bred from sorghum plants during the year were *Atherigona soccata*. Other species obtained, though rarely, included A. *orientalis*, A. *approximata* and A. *eriochloae*. A. *soccata* was also obtained from maize, pearl millet, and the wild grasses *Echinochloa colonum*, *Eriocholoa procum*, *Cymbopogon sp.*, and *Paspalum scrobiculatum*. Many other species were reared from wild grasses during the year.

Experiments with shoot-fly attractants showed that fish meal is strongly attractive, especially 4-8 days after mixing with water, but its "pull" can be doubled by supplementing with Ammonium sulphide plus Brewers yeast. Oviposition studies showed that maximum egg numbers are laid at close plant spacings, but the greatest percentage of plants attacked was obtained at 10-20 cm. spacing. Some 10 ha. of germplasm and breeders lines was screened for resistance. Indian sorghums identified as resistant in AICSIP programmes also showed up well in our screening trials, and we are confident we now have a reproducible field screening methodology suitable for handling large numbers. Some Indian x W. Africa derivatives showed marked non-preference. Preliminary plant morphology studies indicate that trichomes may be associated with non-preference, and behavioural studies indicate that chemoreception may be involved in selection of oviposition sites.

Detailed studies of carry-over in stalks of various cultivars for the stem-borer *Chilo partellus* showed high levels of parasitism, and five parasites were identified. On the ICRISAT site, a significant population of stalks carry *Chilo* at the start of the kharif season, but in farmers' fields, none could be found during the period March-May. A "close season" on the site is thus important. Synthetic *Chilo* pheromones were studied in field traps in co-operation with TPI London. Progress was made in developing suitable media for rearing *Chilo* in the large numbers required for screening in the resistance breeding programme, and the possibilities of utilizing natural attack were also looked at.

Midge attack at Patancheru was low, and parasitism high, three parasites being identified. We shall need to screen for midge resistance elsewhere.

PATHOLOGY

A total of 4036 germplasm and breeding lines were screened for resistance to grain moulds, using innoculums of *Fusarium* and *Curvularia*, supplemented by natural mould infection during the prolonged rains. Three lines showed very good resistance and 90 good resistance, but these results must be reconfirmed. The screening technology was tried in the rabi season, and in spite of reduced seed set under the bags on the heads, grading for levels of mould was again possible. Microfloral and seed treatment studies showed that grain mould infection may reduce germination to around five percent in evidently mouldy grain, but even apparently clean grain from mouldy heads may show only twenty percent germination. Seed treatments gave some improvement for the latter material, but virtually none for the evidently mouldy grain. Benlate was most effective in reducing fungal infection.

Preliminary tests indicate that it should be possible to screen material for resistance to downy mildew and several leaf diseases in the kharif season (but not in the rabi) by using spreader rows (infector lines).

PHYSIOLOGY

A variability study on 49 genotypes of various characteristics in growth stages 1 to 3 (GS1, GS2, GS3) was done. The duration of GS1 (vegetative phase) varied from 30 to 41 days: that of GS2 (head development phase) from 31-64 days, and that of GS3 (grain filling phase) from 31 to 56 days. There were substantial differences between genotypes in leaf number, rate of leaf production, position of the largest leaf, grain yield, seed number, seed size, grain filling rate, and number of nodes per head, in addition to differences in other characters. Grain yield per season varied from 20.6 to 72.9 kg/ha per day, and yield per day for GS3 only varied from 58.6 to 273.4 kg/ha. We can now begin to use the variation identified in a breeding programme to develop more efficient plants.

Forty entries from elite selections were studied to define the range in variability in nitrogen uptake and distribution, and possible influences on yield. Nitrogen uptake per plant varied from 0.22 g to 1.14 g, and nitrogen transfer efficiency (NTE) from 57.8% to 86.6%, at a given total nitrogen uptake there were genotypes with an efficiency of over 77%. The expected weak negative correlation between grain yield and grain nitrogen concentration was found ($r = -0.36^{*}$). Grain nitrogen was highly correlated with total biomass ($r = 0.77^{***}$), so large plants tend to have more nitrogen. NTE and Harvest index were strongly correlated ($r = 0.83^{***}$) so high harvest index requires high NTE: grain yield was positively correlated with total plant nitrogen ($r = 0.51^{***}$), grain nitrogen content ($r = 0.58^{***}$) and NTE ($r = 0.33^{*}$). Set against the rather weak negative correlation with grain nitrogen concentration ($r = -0.36^{*}$) this suggests that high yielding genotypes with a high nitrogen concentration can be obtained which would need selection of types with above average nitrogen uptake and maximum transfer of nitrogen from plant to grain.

Seventy eight genotypes were studied in petri dish, pot and field for seedling, root and panicle development. Results showed that the absolute weight of seed reserves mobilised for new growth during germination increases with seed size, but from 15 to 30 days, the association between seedling size and seed size is not very strong, so not all big seeds produce big seedlings, which relates to the photosynthetic area and efficiency of the seedling.

Brick chambers were used for root studies, and showed that the average day weight of roots per plant at all stages was greater for the Pioneer hybrid 22 E than for CSH-1. Field studies of panicle development in these hybrids, and their parents, showed that 22 E deviated considerably from its parental developmental time table, but CSH-1 did not.

Seventy four genotypes were evaluated in the field for drought resistance under a stress period of 30 days beginning at the panicle initiation stage. An evaluation procedure based on the effect of stress on growth cycle length, absolute yield under stress, and yield decrease compared to no stress has been developed. Resistant types with an avoidant response (growth cycle changed by less than 7 days) and resistant types with a tolerant response (growth cycle extended by 7 to 30 days) were identified, together with intermediate types. We consider that a resistant type should be capable of yielding 20 q/ha under artificial stress, with no more than 30% yield reduction relative to "no stress" conditions.

MICROBIOLOGY

During the rabi season 115 sorghum entries, known to perform well under both low and high fertility conditions, were grown under low (20N: 20P_2O_5) fertility conditions. Acetylene assay of the nitrogenase activity of the washed root systems showed up to forty fold differences in activity, with a maximum of 1.2 Umol/q dry weight of root/h. There was substantial variation between plants within lines as well as between line means. High nitrogenase activity was associated with 10 entries, including CSH-1, CSH-5 and *S. halepense*, and was greater after flowering than previously in these irrigated plants. We are concentrating on developing a suitable assay system to identify reliably lines which stimulate much nitrogen fixation.

BIOCHEMISTRY & NUTRITION

Some 7000 sorghum samples were screened for protein content and total basic amino-acids (which includes lysine). The biuret method for protein estimation was discarded in favour of the microKjeldahl and the Technicon systems. The UDY test was used throughout to estimate total b.a.a. and therefore lysine. Twenty three samples sent to the TPI, London, for starch and fibre analysis showed a negative correlation of starch with protein (-0.68**) and with fibre (-0.70**). Protein was positively correlated with fibre (0.77**), and 100 grain weight was not correlated with protein, fibre or starch.

PROGRESS IN BREEDING FOR IMPROVED LYSINE

CONTENT OF SORGHUM GRAINS, 1973-75

A) MATERIAL

The following material was received from Purdue in time for planting in Rabi 1973.

(1) 39712011 328 to 39713098 999 (397328 - 397999). 648 entries. These consisted of F_2 seed, from selfed plants of crosses between Purdue populations (PP1R, PP2B, PP3R), Nebraska populations (NP3R), a source identified as ms_3 (presumably Coes) Redlan, IS 5614, and IS 5623, used as female parents, and pollinated by the Ethiopian high lysine cultivars, either IS 11167 or IS 11758. 397721 - 730 consisted of crosses between IS 11758 as female and IS 0855 as pollinator. 397731 - 754 were inter-crosses between IS 11167 and IS 11758. 397787 - 821 consisted of crosses between IS 4668, or IS 5376, as females, and IS 11758 or 11167 as males.

(2) 39631064 001 to 39642016 752. (396001 - 396752) 651 entries. These were essentially backcrosses in relation to the *hl* gene. The "recurrent parent" was 73 PP2B, a high protein yield, non-restorer selection: 73 PP1R, a high protein yield, restorer selection: 73 PP6B, a high yield non-restorer selection, or 73 PP5R, a high yield restorer selection. The donor parents were crosses of the 397 series type, but confined to PP1R, PP2B, or PP3R, with a very occasional Redlan or ms_3 crossed with IS 11167 or IS 11758. Pollen for the 396 series of crosses was taken from the F_1, and no attempt was made to stick with the "B" and "R" separations. Both IS 11167 and IS 11758 were classed as non-restorers (B lines).

(3) 39353071 310 to 39357102 566 (393310 to 393566) 266 entries. These had similar pollen parents to the 396 series, but the female parents

were plants from Bruce Maunder's yellow endosperm population. Pollen was collected from the F_1 generation of the (PP x hl) cross.

(4) 39022004 061 to 39025052 338 (390061 to 390338) 84 Entries. These are much the most complex of the crosses to describe concisely. NP2 and NP3 were crossed to IS 11167 or 11758: all dented seed segregating in the F_2 of these crosses was pooled and labelled "73 PP9". This is the main parent through this series, used as the male except for 390201 to 390239. Groups of parents shown below were crossed to either NP2B or NP3R, and F_2 plants segregating from these crosses were pollinated with 73 PP9:

(i) 350 series: Having high sulphur contents: which included IS 1295, IS 3290, IS 4328, IS 6065, IS 6774, and IS 6908: in addition, there were 78473 and 78515 of unknown origin, but almost certainly IS lines.

(ii) 351 series: IS 0003, IS 0005, IS 0079 and IS 0157.

(iii) 352 series: High oil selections, IS 1259 and IS 2944.

(iv) 353 series: Yellow endosperm selections: including IS 2840, IS 3915, IS 3932, IS 4736, IS 7886, IS 8305, IS 10304, IS 10472, and IS 10723. Also the presumed but unidentified IS row 79406.

(v) 354 series: High Protein lines: IS 0035, IS 0211, IS 0501, IS 0657, IS 1486, IS 2283, IS 2341, IS 2401, IS 2874, IS 2881, IS 3138, IS 3979, IS 4923, IS 5568, IS 6027, IS 6203, IS 6992, IS 7118, IS 7243, IS 7886, IS 8160.

(vi) 355 series: White seed selections: IS 0174, IS 0222, IS 0803, IS 1059, IS 3496, IS 3681, IS 3792, IS 3950, IS 4004, IS 4736, IS 4886, IS 5275, IS 8335, IS 8666, IS 8752, IS 8760, IS 1149, IS 10244, IS 10248, IS 10250, IS 10252, IS 10254, IS 10261, IS 10264, IS 10489, IS 10491, IS 10493, IS 10497, IS 10505, IS 10508, IS 10560, IS 10567, IS 10572, IS 10580, IS 10594, IS 10601, IS 10648, IS 10917, IS 10943 and IS 10648.

(vii) 356 series: Large seed selections: IS 10932 and a partially converted line from Texas, 954062.

(viii) 357 series: High yield selections: IS 0057, IS 4225, partially converted line 954206, and the Purdue lines 956032 and 932296.

(ix) 367 series: Straight crosses of some of the above IS numbers to 73 PP9.

(x) 316 series: Straight crosses of IS numbers, partially converted lines, or Purdue lines, to 73 PP9, except for six entries which were 73 PP9 x (NP3R x 11167).

B. BREEDING

1973 RABI (SHORT DAYS)

Out of the total of 1649 entries received, 454 with sufficient seed were sown in 9 m. rows, and the remainder in 3 m. rows. ms_3 was segregating in a lot of the rows, and sibbing and selfing were done. All plants with white and red seeds (heads) were screened on the light box, and 300 with a very few plump, opaque seeds were identified. The following groups of selections were taken:

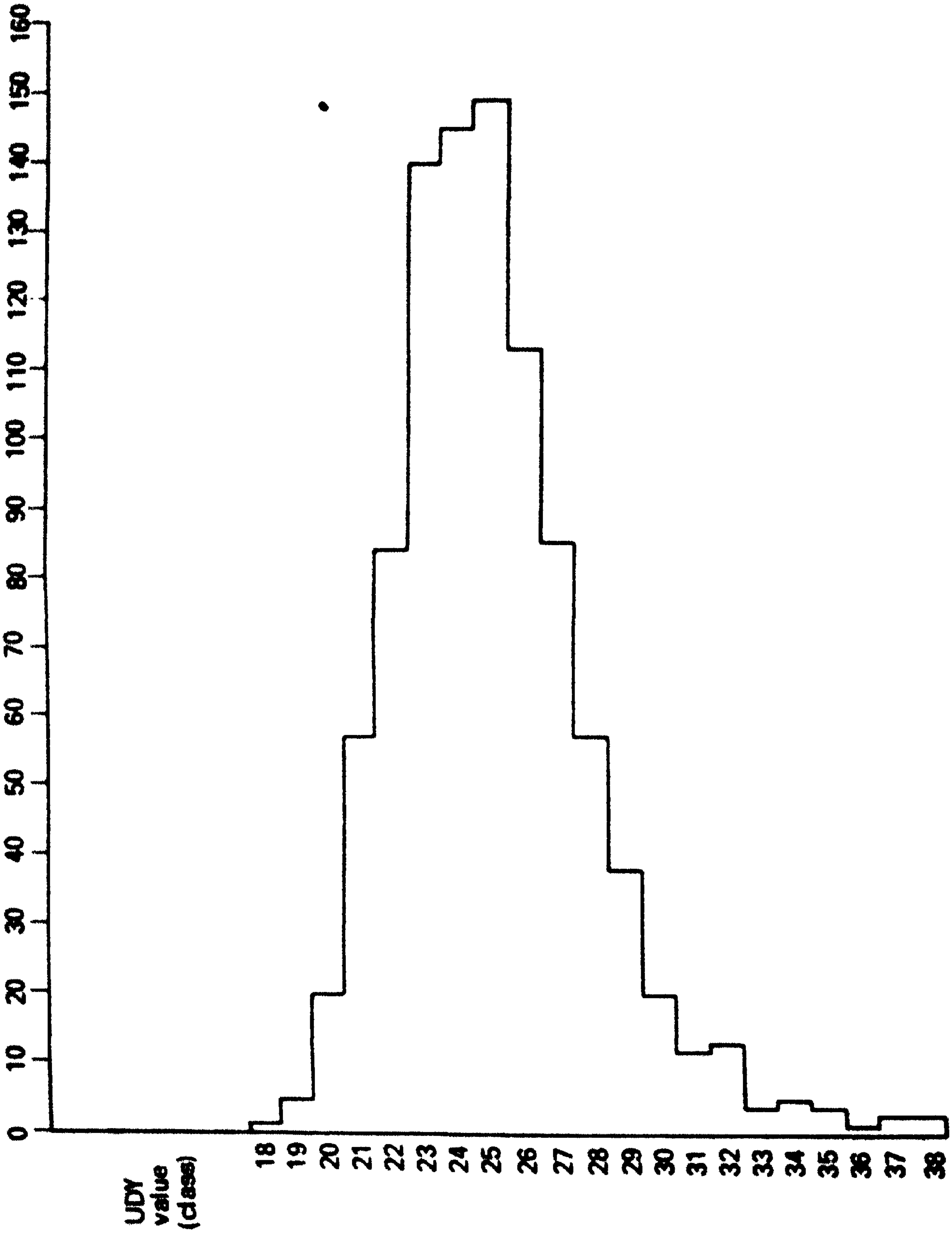
(A) Plants with plump, opaque seeds	300	selections
(B) White, plump non-opaque heads from rows which had segregated for plump opaque	900	"
(C) White, plump non-opaque heads from rows which had not segregated for plump opaque	275	"
(D) Red, plump seeds from heads segregating for <u>hl</u>	1,350	"
(E) Sibs from rows segregating for <u>hl</u>	750	"
(F) In the summer, 1,000 heads with white seeds, which had already been screened on the light box, were analysed chemically by biuret for protein content, and UDY, after removing the pericarp, as shown in Figure 1. The intention had been to analyze many more, but the heads got "lost", one of the results of working in makeshift conditions.	102	

1974 KHARIF (LONG DAYS)

Of the 300 selections in Group A, plants were obtained from only 240 seeds in 140 of the progeny rows. Intercrossing was done, as ms_3 was segregating, 105 plants being used as parents.

The Biuret and UDY screening method was looking very promising, and selection on the light box would only give opaque types

FIGURE 1: FREQUENCY DISTRIBUTION OF UDY VALUES FROM BIURET/UDY SCREENING OF 1000 SEGREGATES OF CROSSES & BACKCROSSES WITH IS 11167 & IS 11758



which had the wrong kind of endosperm. This was therefore discontinued, and emphasis was placed on chemical screening. This decision automatically put a ceiling on the numbers which could be handled. Removal of the pericarp was also discontinued, being very difficult to do successfully for some of the grains with very soft endosperm.

The rains were prolonged, with resultant grain mould, and chemical screening was judged to be misleading in the presence of mould. Selection was therefore based on agronomic characters, with white/yellow grains strongly favoured, since the red and brown pigments probably interfere with the UDY readings. Selection was biased against tall, late, photoperiod-sensitive types. Thus, in this generation, there was no selection for either protein or lysine contents, although in the case of group (F) the numbers of selections taken from each row was influenced by the UDY value of the parent head.

There was a strong preference for the shorter, more vigorous plants in the selections from groups B, C, D and E.

1974 RABI

The main chemical effort went in to screening the descendents of the 1,000 heads screened by biuret and UDY (Group F). There were 309 rows of these, and several heads were screened in each row. It had become clear that the biuret estimate of protein was unreliable, especially at the low protein end of the scale, so the most promising entries identified by this system were re-screened using microKjeldahl and UDY. (We were still not well enough organized to do large numbers of microKjeldahls). Results were expressed on a constant protein basis.

1092 plants from the 309 rows of group F were analysed, and 128 plants from 54 rows qualified for rescreening with MKJ and UDY. Finally, 20 selections from 12 rows were retained as having high UDY values at constant protein, with plump grains having a slight corneous-outer endosperm shell (Table 1). All of these entries showed MKJ protein values of 9.4 percent or less, so we were selecting low protein types, presumably with low prolamine.

The opaque group (Group A) together with their intercrosses, were also screened chemically. 8.6 heads from 425 progeny rows (themselves from selections out of the original 140 rows) together with some of the crosses, were screened similarly. 38 heads from 26 rows were finally selected, together with 8 of the intercrosses.

TABLE 1: HIGH UDY SELECTIONS TAKEN IN 1974 RABI DERIVED FROM THE BEST R73 SELECTIONS CHOSEN ON BIURET + UDY ANALYSES (80 mg. PROTEIN)

Row No.	Plant No.	1973 UDY Value	Biuret Protein	UDY Value	mkj protein	UDY Value	Row No.	Plant No	1973 UDY Value	Biuret Protein	UDY Value	mkj protein	UDY Value
79135	8	(37.5)	8.0	32.5	8.9	28.5	79335	6	(30.0)	6.3	36.5	7.6	29.5
79429	4	(34.0)	8.0	30.0	8.1	29.0	79337	2	(30.0)	6.3	35.5	7.2	30.0
79175	2	(30.5)	8.2	30.0	7.9	30.0	"	3	(30.0)	6.7	33.0	7.3	30.0
79233	7	(30.0)	8.7	30.0	9.4	28.0	"	4	(30.0)	6.3	34.0	7.2	31.5
"	8	(30.0)	8.0	31.0	9.0	28.5	79339	1	(30.0)	7.2	33.0	8.1	28.0
79235	5	(32.0)	9.0	30.5	9.4	28.0	"	2	(30.0)	7.3	32.0	7.8	29.0
79283	1	(32.0)	7.3	35.0	8.6	29.0	"	3	(30.0)	6.0	37.5	7.1	30.5
79287	1	(32.0)	6.3	38.5	8.1	28.5	"	8	(30.0)	7.2	31.5	7.8	29.0
79327	2	(30.0)	6.3	38.0	8.0	28.5	79449	1	(30.5)	6.0	32.0	7.0	28.0
79335	5	(30.0)	6.7	33.0	7.8	29.0	"	1	(30.5)	6.7	31.0	7.4	28.5

The remaining groups of rows from the original R6 kharif selections were then screened, as far as possible, preference being given to the best agronomic types with plump grains. 2250 were screened using biuret/UDY, and 78 were identified as high lysine, as we felt confident that a big enough discount for the weaknesses of the method had been made. In fact, when it finally proved possible to do the MKJ and UDY method, only three of these qualified. There seemed to be an encouraging association between Rabi 1973 values and progeny values two generations later (Table 2).

1974 RABI

TABLE 2: ASSOCIATION BETWEEN UDY VALUE (80 MG. PROTEIN) OF SELECTIONS RABI AND PROGENIES TWO G[illegible] (BIURET + UDY SCREENING)

UDY value of 1973 rabi head selections (class)	No. of progeny rows two generations later: UDY > 30	UDY < 30	Percent of rows with high UDY	No. of heads: UDY > 30	UDY < 30	Percent of heads with high UDY
28-29	6	59	9.2	9	192	4.5
30-31	21	58	26.6	42	466	8.3
32-33	12	29	29.3	27	182	12.9
34-35	5	8	38.5	12	56	17.6
36-37	7	6	53.8	37	62	37.4

ADDITIONAL MATERIAL

Purdue University supplied seed of crosses between some of Doggett's Uganda populations, and F_1 plants of the 316 series. The Uganda populations were Puerto Rico Dwarf (DPRP) Good Grain (GGP), Hybrid Rs. (HRSP) and Red Flinty (RFP). The 316 series were PP_1, PP_2, or PP_3 (NP3 was used on two occasions) crossed with either IS 11167 or IS 11758.

403 rows of DPRP, 69 rows of GGP, 87 rows of DRF, and 186 rows of DHRS, were grown, no analyses were done, but selections were taken, choice being made on grain colour, head weight, height and vigour. These selections were planted at Bhavanisagar in the summer, and had

been chosen on agronomic characters only.

1975 KHARIF

All the material which successfully passed the screening test from the rabi and summer plantings 1974/75, was classified as follows: Group I, UDY of 30 or above: Group II, UDY of 29: and Group III, UDY of 28. In addition, there was the "good agronomic characters" group of 78 entries which had originally been thought to be high UDY, based on biuret protein estimates: and the Uganda bulks x 316 from the Coimbatore summer planting. There were two planting dates for some of the material. In addition, some head rows of P721 were grown, as well as some more Purdue material, involving the 411, 412, 414 and 417 series, consisting essentially of F_2 selections (F_3 in R6) from the series, involving Maunder Yellow, PP1, PP2, PP3 or PP4(?) crossed with (NP2 or NP3) x (11167 or 11758).

The Technicon apparatus for protein estimations had now become available, and it was possible to screen 2880 samples, several plants per entry being taken, more in the high groups than in the others. Table 3 shows the relationship between the plants identified from the Kharif 1975 harvest as having high UDY values, and the UDY values of the parent head with which the progeny row was planted.

TABLE 3: RELATIONSHIP BETWEEN UDY RATINGS FOR THE PARENT HEADS OF THE 1975 KHARIF PROGENY ROWS, AND THE RATINGS FOR THE SELECTIONS CHOSEN

Parent rows		UDY Group (constant protein) of kharif selections						
		I (30+)		II (29)		III (28)		IV (<28)
No. of entries	Description	No. of entries	No. of selections	No. of entries	No. of selections	No. of entries	No. of selections	No. of entries
17	UDY Group I	11	18	1	2	1	8	4
17	UDY Group II	1	1	1	1	3	3	12
25	UDY Group III	2	2	0	0	3	6	20
78	UDY Group IV	3	4	1	1	1	1	73
113	Opaque intercrosses	13	21	2	5	5	10	93
693	Uganda populations	9	9	2	2	6	7	676
22	P721 headrows	1	1	1	1	1	1	19

The trend is as expected: the proportion of selections with high UDY values is highest where the parent heads were highest. The numbers are not at all as expected: the frequency of the high UDY segregates is very low: and the protein levels of the progenies were much higher than those of the parent heads. At the time, this latter effect was thought to be seasonal: for the first time, we had data from a kharif harvest. Earlier data had all been from rabi or summer plantings.

RABI 1975 & SUMMER 1976

Three groups of the selections were chosen for combining into populations. Group A, with very high UDY values per 80 mg. of protein (30+) contained selections from seven lines: Group B, UDY value of 30-38.5, contained selections from 28 lines: and Group C, consisting of the model UDY values 28-29.5, contained selections from 25 lines. P721 selections were added to each of these groups, and within group inter-crossing, using the segregating male-steriles was begun at Bhavanisagar in the summer.

Additionally, intercrosses were made between the best P721 lines and the high UDY derivatives from this hl crossing programme.

Only some of the laboratory results are at present available, but these are showing the same trend as that found in the kharif season-high protein levels, with reduced UDY values. Table 4 illustrates what has happened in the history of selection from two good Rabi 1974 lines, 80079 and 79337. High lysine selections have not disappeared completely. thus, in analysis of 31 plants out of four high lysine lines from Bhavanisagar, seven quality as high lysine (UDY of 28+) and one or more of these occurs in each line. Incidentally, in this season, UDY values were taken on 1 gm. of sample, and the 80 mg. equivalent was calculated on a proportional basis.

DISCUSSION

The puzzling aspect of the work so far has been our inability to produce true breeding high lysine lines with plump grains, or indeed, to raise the frequency of occurrence of such plants by very much. One first questions whether we have been dealing with high lysine plump grains at all, or whether we have been handling artifacts resulting from analytical errors. This year, a trial of ten entries in four replications was fed incognito into the analysis pipe-line, in among the breeders' samples, with the results shown in Table 5. On the whole, these are satisfactory for breeder's purposes. There is evidently one serious error of protein estimation in entry 7 (BP53) Rep. IV, and the

TABLE 4: BEHAVIOUR OF HIGH LYSINE SELECTIONS OVER GENERATIONS, UDY VALUES WITH PROTEIN VALUES IN BRACKETS, MEANS & RANGES

Selections from Rabi 74	Kharif 1975: Row means & ranges		Kharif 1975: Selections	Kharif 1975: Values	Rabi 1975: Selections	Rabi 1975: Values		Rabi 1975: Row means & ranges	n	Controls
80079-1 (7.5) 32.5	2011 (n = 30) (11.0) 24.7	(6.0 - 14.3) 21.5 - 44.5	2011-15 (8.7)	33.0	1669	(18.1)	(17.5 - 18.8)	24.6, 23.4 - 25.8	2	CSH-1 (12.4) 23.2
			2011-16 (7.8)	31.5	1670	(15.7)	(14.9 - 16.2)	23.8, 21.8 - 25.2	3	CSH-1 (12.6) 23.5
			2011-17 (6.0)	44.5	1671	(15.1)	(13.4 - 17.0)	24.1, 22.7 - 25.4	10	P721 (15.5) 31.5
			2011-19 (7.2)	35.0	1672	(14.5)	(14.0 - 18.3)	24.5, 22.6 - 25.8	6	P721 (15.9) 30.7
			2011-20 (8.3)	37.0	1673	(16.4)	(13.4 - 17.9)	23.1, 18.3 - 25.4	9	148 (13.7) 22.8
79337-2 (7.2) 30.0	2002 (n = 7) (10.9) 23.6	(7.0 - 13.4) 21.0 - 32.0	2002- 6 (7.0)	32.0	1651	(13.8)	(11.1 - 16.4)	23.9, 21.0 - 26.6	15	148 (13.6) 21.2
79337-3 (7.3) 30.0	2003 (n = 20) (10.5) 23.5	(7.9 - 12.7) 21.0 - 32.0	2003- 4 (7.9) 2003- 8 (8.7)	34.0 28.0	1652 1653	(12.3) (11.6)	(9.4 - 15.5) (10.4 - 13.8)	24.7, 22.0 - 28.5 23.9, 21.0 - 27.0	21 30	CSH-1 (12.0) 24.0 CSH-1 (12.4) 23.8
79337-4 (7.2) 31.5	2004 (n = 25) (9.7) 24.5	(6.1 - 13.6) 20.0 - 32.0	2004- 1 (8.6)	32.0	1654	(15.2)	(11.3 - 17.0)	24.4, 22.9 - 25.0	10	P721 (15.3) 31.6
			2004- 4 (8.3)	31.0	1655	(13.0)	(12.1 - 17.1)	23.3, 22.5 - 28.2	17	P721 (16.1) 31.0
			2004-20 (7.2)	28.0	1656	(13.0)	(11.3 - 15.8)	23.5, 22.2 - 25.9	18	148 (13.6) 24..
			2004-25 (6.1)	32.0	1657	(14.2)	(11.8 16.6)	23.3, 20.0 - 25.1	14	148 (13.9) 23.0

fluctuations in UDY values for entry 3, Swarna, are large. The control entries were also fed incognito as one in ten of the samples, and good consistency of estimates was obtained, as can be seen from the control entries in the last column of Table 4, which were those associated with the samples presented in the table. Further, both Table 2, and Table 3 indicate clearly that there is a greater probability of finding high lysine plants in rows sown from high lysine heads. There is always room for improvement, and it is not easy to push 3,000 to 4,000 samples through a temporary laboratory within one month without occasional error: but we do not think that such occasional errors can explain our results.

TABLE 5: RESULTS OF A TRIAL FED INTO THE ANALYSIS PIPELINE INCOGNITO

P = Protein U = UDY per 80 mg.

Variety	Replication							
	I		II		III		IV	
	P	U	P	U	P	U	P	U
1. 148	13.3	22.9	13.0	24.0	12.9	23.9	13.3	22.9
2. 370	13.2	25.5	13.9	23.3	12.7	25.8	12.9	24.8
3. Swarna	11.0	24.7	10.8	28.9	10.8	23.7	12.2	23.0
4. 3541	11.5	25.4	not yet analysed		11.2	25.7	11.7	24.6
5. R-16	10.3	24.1	13.1	25.0	11.6	24.1	14.4	23.9
6. 302	12.9	23.6	12.7	24.4	12.5	24.6	13.0	22.8
7. BP 53	7.2	28.9	7.6	27.9	7.1	28.2	12.6	15.6*
8. P-3	13.5	20.7	13.2	21.8	13.4	21.2	13.0	21.2
9. 269	8.2	28.3	8.6	27.0	8.4	25.7	8.4	25.7
10. 327	12.5	24.3	12.6	24.4	12.5	23.7	13.1	22.6

* For a protein value of 7.0-7.2, this UDY value would lie between 27 & 28.

More data are required: but it seems much more probable that the explanation of our results lies in the instability of the hl gene when in a normal (plump seed) endosperm background, as opposed to the shrivelled background in which it persists in Ethiopia. There is good reason to believe that recombinants between seed plumpness and the opaque endosperm of the hl lysine gene do occur: we found them, as did Shri Pal Singh: yet they have not yet been identified in Ethiopia, although many normal types were collected from Ethipian fields where the hl forms were growing, and analysed. This argues for instability of the hl gene in normal backgrounds. Our data point the same way: For example, in Table 4, the high UDY types have low protein contents: yet some of their progeny have protein contents, not just a few percentage points higher, but double the parental value. If hl suppresses prolamine development, as is probable, then the revision of hl to Hl will result in a sharp increase in total protein content, which appears to be occurring. We hope that a post-graduate student, Mr. Ken Riley, will be able to confirm or deny these speculations during the coming two years. It is possible that the crosses with P721 may help to stabilize the hl gene.

Incidentally, the figures for BP53 in Table 5 are also of interest. Three other collections made this rabi season showed a similar tendency. There may be material here in India which under environmental conditions conducive to low protein production reduce the prolamine produced and so give "high lysine" results. We hope Ken Riley may look at this also.

INTRODUCTION

The goal of our programme is the development of sorghum cultivars which will give improved, consistent yields coupled with highly acceptable grain quality. The intention is less to produce finished materials than to provide local programmes with good base line cultivars which can be developed into excellent varieties or hybrid parents by National research workers.

Yield improvement requires the refashioning of traditional photoperiod sensitive, long-duration sorghums to obtain a greater proportion of the dry matter production per unit area as grain. This demands photoperiod insensitivity, which in turn requires the best possible matching between crop duration and rainfall distribution. We are developing Advanced Composite Populations of several maturity lengths, appropriate for different rainfall belts in Africa. We have little long-term photoperiod insensitive material at present, but the Earliness with Mould Resistance, and the Grain-Grass projects, are producing good, short-term types, which will also have a place in multiple cropping systems.

The Population Improvement projects utilize a broad range of germplasm. The standard of the population is steadily improved by selection and recombination which is an effective way both to obtain better, more consistent yields, and to produce base line material for National programmes. Good progress is reported, especially in the Fast Lane populations. The Plant Physiology project reports the identification of genetic variability in a wide range of characters related to crop and grain development. We can now begin breeding for more efficient plants.

Pests become extremely important when traditional varieties and practices are changed: the Pest Resistance project reports progress in obtaining good levels of shoot-fly resistance, and the Entomologists are developing the technology to screen for resistance to both borer and midge. The Pathologists are developing the methodology of screening for resistance to the more important diseases, and the striga resistance project is identifying varieties with resistance due to low production of "strigol" stimulant. The abandoning of traditional sorghum varieties results in the need to reassemble the whole complex of resistances and other adaptive factors in new material. ICRISAT's Germplasm Collection gives the opportunity to accumulate better levels of adaptation than previously existed, through bringing together germplasm from diverse sources.

The achievement of maximum yield per unit area with optimum inputs cannot be an objective of importance to ICRISAT for many years to come. Only an additional 700 kg/ha of grain are required to double sorghum production in the Developing World. Stability of improved yield must be our prime target. There are large differences between varieties in yield stability which can only be identified by selection and testing across locations. Fortunately, screening across locations is as effective as screening across years. The International Testing project reports a beginning in the development of this vitally important activity at sites in India and Africa, with some trials done at low soil fertility levels. We are receiving great co-operation and help here within India, and hope to develop a range of preliminary screening sites from 22½°N, to 8°N, covering also places where special disease, striga, or pest situations occur. An "off-season" nursery at an "in-season" site is included.

The Plant Physiology project's studies on the differences between genotypes in kinds and levels of drought resistance are very important in our breeding for yield stability, and interesting progress is reported. Nitrogen is required to obtain good cereal yields. The Microbiology project and the Plant Physiology project hold out the exciting possibility of breeding sorghum cultivars which can produce their own nitrogen requirements through symbiotic association with bacteria, and which utilize the nitrogen produced more efficiently in the production of grain.

Grain quality improvement must be one of the pillars of the programme. The move away from photoperiod sensitivity results in grain sometimes ripening under wet conditions. Resistance to grain mould, or protection from it, is therefore essential. The Plant Pathologists report progress in both the technology of inducing grain mould attack and in the identification of resistant types. The Earliness with Grain Mould project records the progress being made in breeding these resistances into cultivars, and in the perfection of large, protective glumes. We still lack basic knowledge of the characters which control good cooking quality as esteemed by the housewife, and are developing co-operative arrangements with CFTRI and NIN to correct this deficiency. The high lysine work has continued, but a long process of combining this character with good cooking and flavour characteristics may lie ahead.

One of the "way-out" projects, Grain-Grass Sorghums, has moved more rapidly towards immediate usefulness than had been expected. This very different plant type shows promise of unusual earliness, good ratoonability, good drought resistance, good levels of other resistances, combined with the photosynthetic efficiency of the small leaf and high plant populations which can be used with short, more slender plants. The Tetraploid Sorghum project records crosses with wild *halepensis* types to move some of the excellent adaptive characters of this group into the cultivated sorghums. The High Altitude project is in abeyance at present, in view of the work in progress in Ethiopia and Mexico.

The germplasm group report about 14,240 accessions are now available at ICRISAT, and illustrate how the collection is being screened for resistances to grain moulds, other diseases, pests, striga, and drought.

A departmental newsletter "Semi-Arid Cereals" was begun, in order to develop and maintain improved contacts with cereals workers in the Semi-Arid Tropics.

BREEDING (A) YIELD

THE IMPROVEMENT OF COMPOSITE POPULATIONS BY RECURRENT SELECTION

This improvement programme is divided into three projects: (i) Source, the creation and shaping of new composite population; (ii) Back-up, the slow improvement of populations aiming to conserve much of the useful genetic variability; (iii) Advanced, in which the prime objective is rapid progress to achieve material immediately useful to National programmes and to farmers.

Source Populations

Five populations are under development. These are (1) Diallel from 45 World Collection entries, (2) Synthetic from the best AICSIP releases, (3) Photoperiod sensitive, (4) Elite East African and (5) B Composite.

Back-up Populations

The seven populations in this group are (1) Collection restorer, (2) Collection non-restorer, (3) Tropical conversion, (4) Serere, (5) West African Early, (6) U.S., (7) High altitude. We are using half-sib testing at two or three locations in India, followed by recombination in a cycle of two generations each year. A total of 6,241 half-sibs were tested, and 1,737 were selected for recombination from all these seven populations during the year.

Advanced Populations

The eight populations in this group are being improved by S_1 or S_2 testing: we were not able to test across locations this year, but tested at two fertility levels on Patancheru.

(1) & (2) Fast Lane, R & B populations: The best ten S_1 lines of each population, selected in Rabi 1974, were diallel crossed in Summer 1975,

and a second random-mating was made in Kharif 1975. About 800 male-sterile heads were chosen from each population and evaluated for qualitative characters in half-sib rows during Rabi 1975. About fifty percent were selected for S_1 testing in Kharif 1976. Selected lines taken from the first cycle of S_1 testing (Rabi 1974) were evaluated in yield trials in Kharif 1975 at two fertility levels (168 selections), and 120 S_3 lines were similarly tested in Rabi 1975 (Table 6). Several entries performed well under low fertility levels, and a useful proportion showed yield levels similar to those of the AICSIP controls.

(3) & (4) US/B and US/R populations: The first cycle of S_1 selection was completed in 1974. 700 half-sibs from US/B and 825 half-sibs from US/R were grown in 1975 K. Of these, 359 and 433 were selected respectively, S_1 lines from them were planted at Patancheru and at Bhavanisagar (Tamilnadu). 194 lines from each population were selected. Trials of these S_2 lines have been despatched to 3 locations in India, 4 locations in West Africa and 1 in East Africa.

(5), (6), (7) & (8) RS/R, RS/B, Serere elite, and Tropical conversion: The original populations were partly photosensitive and had a high frequency of brown and red grains. Three cycles of mass selection were completed selecting for these qualitative characters. The first S_1 testing cycle was initiated in 1974 Rabi. A total of 1946 S_1 lines from each of these populations were tested in 1975 Kharif, but owing to poor stands in the trials, yield data cannot be reported.

New populations are required to meet the requirements of the differing rainfall belts across Africa north of the equator: rabi conditions in India: and the bird areas of Africa where brown grains have to be grown. These will be assembled from good lines in our existing populations, and some 2000 S_2 lines were evaluated at Patancheru and Bhavanisagar. The best of these have been sent for testing to locations in W. Africa, E. Africa, and India.

Stability & Adaptability of the Populations

A trial of 144 entries consisting of 16 representative lines from each of the populations RS/R, RS/B, Serere elite, High altitude, Bulk Y, WABC, Tropical Conversion, US/B and US/R populations, was conducted at 9 locations in the SAT. Yield data were received from seven locations (Table 7). Mean yields of the photoinsensitive populations (averaged over 16 lines) at each location, and stability parameters are given in Table 7. Figure 2 illustrates the differences in stability of all the populations in relation to the mean of populations. Serere elite and High Altitude populations had a high mean value, and a higher b_i value than unity, indicating that these populations can

TABLE 6: YIELDS OF PROMISING FAST LANE S_2 LINES (1975K) AND S_3 LINES (1975R) IN QUINTALS OF GRAIN PER HA.

	Kharif 1975		Rabi 1975	
	High Fertility Black[a]	Low Fertility Red[c]	Combined	High Fertility Red[b]
B 11	59.6	42.7	51.2	-
R 53	65.8	30.2	48.0	-
R 274	56.8	31.8	44.3	-
R 139	55.4	27.0	41.3	-
B 104	57.0	25.1	41.0	-
R 141	49.6	29.6	39.6	-
R 100	58.9	19.5	39.2	-
R 147	47.0	27.4	37.2	-
CSH-1 (d)	52.2	31.4	41.8	61.3
370 (e)	57.4	20.5	40.0	-
148 (e)	15.7	20.8	18.2	-
R 16 (e)	-	-	-	25.4
B 20	-	-	-	61.5
R 152	-	-	-	58.7
B 117	-	-	-	57.3
B 100	-	-	-	55.6
R 274	-	-	-	55.3
R 139	-	-	-	54.8
R 274	-	-	-	54.1
LSD	16.0	9.4	12.6	13.7
CV	18.2%	19.5%	25.9%	15.0%

(a) High Fertility Black Soil, received 111N:46.5P

(b) High Fertility Red Soil, received 111N:46.5P

(c) Low Fertility Red Soil, received 20N: 9.0P

(d) Hybrid Check

(e) Variety Check

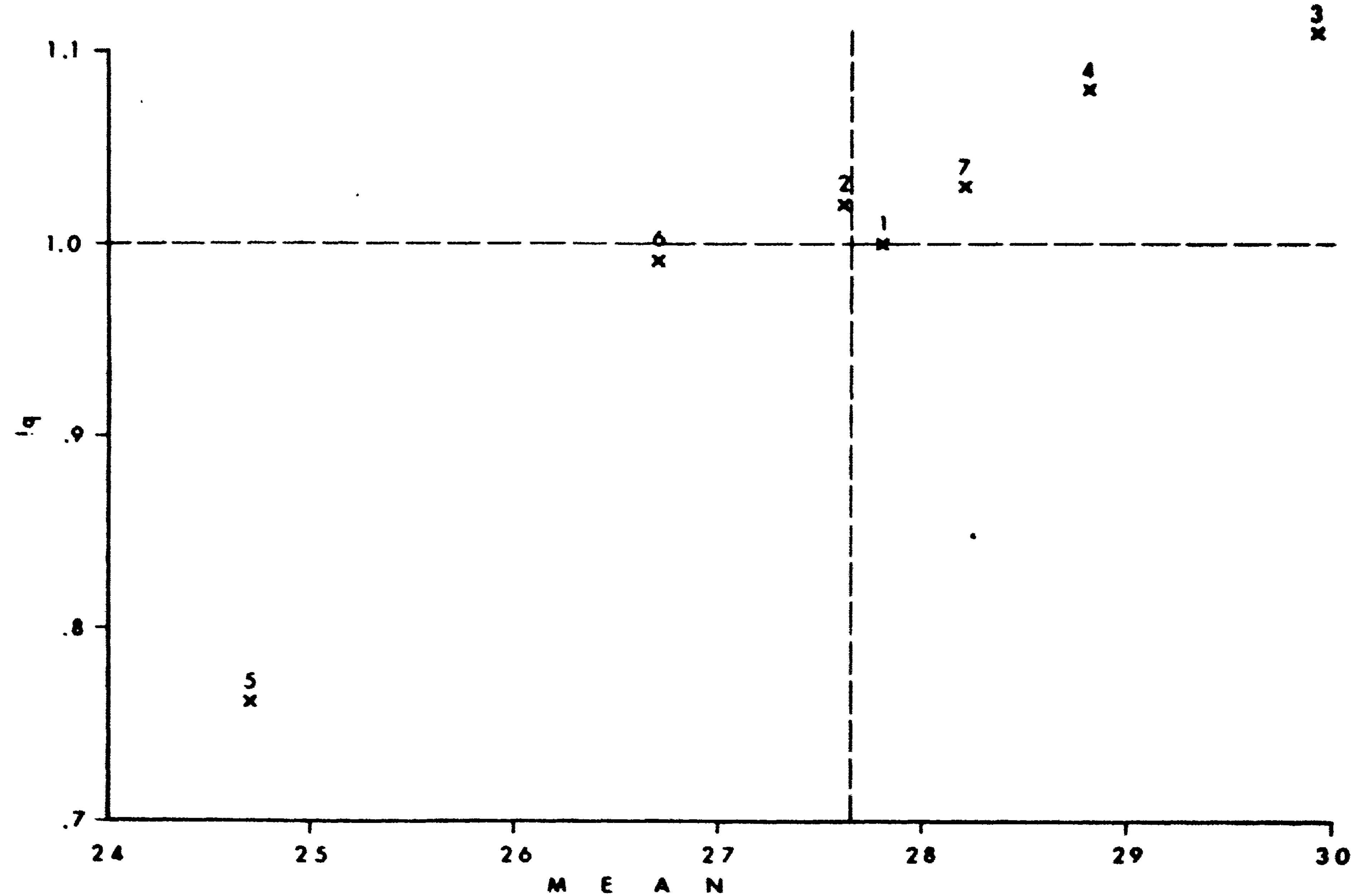
TABLE 7: MEAN GRAIN YIELD (Q/HA) OF POPULATIONS AT DIFFERENT LOCATIONS AND STABILITY PARAMETERS (x_i, b_i and s^2d_i)

Population	L O C A T I O N							Stability[a] Parameters		
	Dharwar	Indore	ICRISAT High Fertility	ICRISAT Low Fertility	Akola	Khon Kaen	Serere	x_i	b_i	s^2d_i
RS/R	45.4	16.2	51.1	21.5	12.5	32.9	14.9	27.8	1.00	-3.21
RS/B	47.6	16.1	50.0	16.8	11.5	33.7	17.2	27.6	1.02	1.98
Serere elite	52.0	17.8	54.2	20.0	12.6	35.4	17.3	29.9	1.11	0.13
High Altitude	50.2	17.3	52.4	22.5	11.0	32.4	14.7	28.6	1.08	-0.80
Tropical conversion	34.8	13.7	44.0	24.4	10.1	29.0	17.2	24.7	0.76	5.84*
US/R	43.6	13.0	50.2	22.9	11.5	31.7	14.3	26.7	0.99	-1.17
US/B	43.5	17.4	54.5	20.8	11.9	33.8	15.2	28.2	1.03	-0.19

* Significantly different from unity at 5% level of significance

[a] Eberhart & Russell, Crop Sci., 6, 1966, 37-40

FIGURE 2 : STABILITY OF POPULATIONS : b_i PLOTTED AGAINST MEAN YIELD



respond to improved environments. US/B and RS/B showed similar behaviour. The Tropical conversion performed reasonably well under poor environments but could not take advantage of better conditions. This analysis gives preliminary information about the average performance of populations, and an analysis based upon individual lines is planned. The performance of some of high yielding lines is given in Table 8.

PEST RESISTANCE

The Pest Resistance breeding has so far concentrated mainly on breeding for resistance to shoot-fly. Our objective is to combine high levels of resistance with a desirable plant type, good yield and acceptable grain quality. Several different breeding approaches are being used:

Pedigree Breeding

This is being used to incorporate resistances into adapted varieties and 26 such varieties (originating from India, West Africa, and East Africa) were crossed to resistant parents in Rabi 1975: 470 crosses for shoot-fly resistance, 93 for stem-borer resistance, and 466 for midge resistance were made.

Pest Resistance Populations

Recurrent selection seems to be the best long-term approach for combining pest resistance with yield and grain quality. In 75 R we began to build a pest resistance population, by using resistant lines as females and pollinating them with lines selected from the advanced populations. The selected lines carry high yield, good grain quality, and either the ms_3 or ms_7 gene. In Rabi 1975, 375 crosses for shoot-fly resistance, 115 for stem-borer resistance, and 285 for midge were made.

Side-cars to Advanced Populations

Most of the advanced populations have a low level of pest resistance. Consequently, seven shoot-fly resistant lines (EN 3255, EN 3257, EN 3309, EN 3332, EN 3337, EN 3342 & EN 3363), one stem-borer resistant line (E 303), and three midge resistant lines (IS 2501C, IS 2597C & IS 2816C), all of reasonable agronomic type, were crossed

TABLE 8: GRAIN YIELD (Q/HA) OF SOME OF THE HIGH YIELDING LINES (1975 K) DRAWN FROM ICRISAT ADVANCED POPULATIONS AT 7 LOCATIONS

Entry No.	Pedigree	Dharwar	Indore	ICRISAT High Ferti-lity	ICRISAT Low Ferti-lity	Akola	Khon Kaen	Sere-re	Mean
45	Serere elite	67.4	19.7	66.7	22.1	19.7	40.8	71.4	45.0
44	Serere elite	68.1	17.6	65.5	30.1	9.6	37.4	74.2	43.2
100	US/R	62.4	23.4	72.0	22.9	10.9	40.5	61.1	41.9
7	RS/R	69.3	2.2	64.7	20.4	11.8	42.3	82.1	41.8
46	Serere elite	62.4	21.3	62.6	30.5	17.2	42.0	50.0	40.9
30	RS/B	63.9	23.0	24.1	55.4	13.3	35.8	69.4	40.7
86	US/R	52.1	23.8	53.0	36.8	16.1	33.7	67.1	40.4
62	High Altitude	68.8	16.6	79.1	15.6	14.8	35.0	52.0	40.3
58	High Altitude	66.7	22.9	55.7	13.7	11.4	30.1	79.8	40.0
109	US/B	46.5	16.2	67.7	19.2	16.6	46.6	65.9	39.8
34	Serere elite	56.3	17.6	57.3	25.3	14.0	31.9	75.4	39.7
33	Serere elite	45.0	20.2	61.2	39.2	15.9	34.4	59.1	39.3
20	RS/B	70.1	14.0	47.8	14.4	17.7	36.7	74.2	39.3
50	High Altitude	57.5	22.0	65.7	26.9	12.9	35.0	54.0	39.1
1	RS/R	57.6	17.4	57.1	17.6	17.2	38.4	68.9	38.8
102	US/B	52.8	26.0	73.9	34.9	15.4	37.4	47.2	38.2
41	Serere elite	56.8	20.4	56.3	20.9	10.0	38.8	63.5	38.1
63	High Altitude	56.9	28.6	55.6	18.8	9.6	32.9	62.3	37.8
23	RS/B	39.6	20.4	57.0	17.3	12.1	34.7	83.3	37.8
70	Tropical conversion	47.2	15.4	65.7	33.2	15.8	34.4	52.4	37.7
	Mean	45.0	15.9	51.2	21.5	11.7	32.7	51.6	32.8

on to five advanced populations (Fast lane B, Fast lane R, RS/R, RS/B, and New good grain). By making one or two backcrosses (the side-car approach) these resistances will be transferred to the advanced populations.

Genetic Studies

A number of crosses involving resistant x resistant and resistant x susceptible parents were made in 75 R to obtain some information on the inheritance of shoot-fly resistance. A post-graduate student will be coming in 1977 to undertake these studies for his thesis project.

One small study was done to determine which generation is best to select for resistance. Parents, half-sibs, S_1, and S_2 lines were grown from WABC x EN and Bulk Y x EN crosses. The proportion of selected lines is given in Table 9.

TABLE 9: PERCENTAGE OF LINES SELECTED FROM DIFFERENT GENERATIONS

	Half-sib	S_1	S_2
Very promising selections	0	10	12
Promising selections	10	2	6

These very preliminary results suggest that resistant genotypes may be eliminated in half-sib progeny testing, probably because of much segregation in the lines. However, resistant genotypes were apparently successfully identified in S_1 progeny testing.

STRIGA RESISTANCE

The laboratory seedling screening to identify low strigol producing sorghums has just started. The spontaneous germination of striga seed in distilled water has been brought down to a reasonable level and the technique is workable now. Such resistance must be confirmed by field testing: a striga sick plot at Patancheru is not yet available, but P.K.V. Akola have agreed to provide this facility. Other areas will be surveyed during the kharif and rabi seasons to identifying "hot-spots" which we may use. *Striga asiatica*, *S. densiflora* and *S. euphrasioides* parasitize sorghum in India.

The Breeding Progr

We received a *Striga hermonthica* resistance composite from Samaru, Nigeria based on the ms_7 male-sterility. This has been random-mated twice at ICRISAT, and 120 crosses made with International nursery and other adapted lines to incorporate photoperiod insensitivity into the composite.

We obtained 42 lines from Africa and India, reported to have differing types of resistance mechanisms, such as Dobbs, Framida, and CSV-5, and 206 intercrosses were made between them in Rabi 1975.

A replicated trial of 200 entries from the germplasm collection, from farmers' types, and from the striga composite, was planted under natural infestation conditions at Patancheru in Rabi 1975. Striga incidence was patchy and only 59 lines could be selected for further screening at Akola in Kharif 1976.

A synthetic strigol analogue from Sussex University, U.K. was evaluated using soil in boxes, and in field plots. Box experiments were done in Kharif 1975 using both red and black soils. 1.5 and 10 ppm of strigol was applied following 21 or 27 days of pre-treatment. Susceptible sorghum (CSH-1) was planted after one month on August 11th and 18th. Striga counts were taken three times, and subterranean striga was also counted at the end of the experiment. There were no treatment differences on the black soil. Data from the red soil test are presented in Table 10. 5 ppm of strigol solution reduced the striga incidence by 46.2% compared to the control. The percentage reduction with 1 and 10 ppm was 14.2 and 24.8. A similar experiment conducted on black soil under field conditions in Rabi 1975 showed no treatment differences, although on average there were 55 striga plants to every sorghum plant. The strigol analogue is unstable under alkaline conditions, and more stable analogues are needed.

Collection of striga resistant lines and striga seed continues. We received 20 lines from Samaru, Nigeria which had undergone four stages of screening against *Striga hermonthica*. They were multiplied in 1975 R and will be sent to Akola for screeing against *Striga asiatica* during 1976 K. *Striga densiflora* and *S. asiatica* seeds from Mohol and Bhavanisagar respectively were added to our collection.

TABLE 10: STRIGA COUNT IN BOXES (RED SOIL) 1975 K

	No. of striga plants			
	R_I	R_{II}	R_{III}	Mean
1 ppm	29	36	55	40.0
5 ppm	19	5	10	11.3
10 ppm	10	38	38	28.7
Control	48	82	86	72.0
L.S.D. (P=0.05)				25.5
CV				24%

The physiologists collaborated in sectioning the young roots of resistant and susceptible varieties of sorghum to identify anatomical features which may be associated with mechanical resistance. Preliminary results were encouraging.

INTERNATIONAL TESTING OF BREEDING MATERIAL

International Trials

In 1975, four trials were sent to various locations in Africa, India, S.E. Asia and S. America. Data have been returned from only some of the sites.

Trial 1: Contained 49 entries, of material from the AICSIP and ALAD programmes, with some good world collection and EC (exotic collection) entries, together with some ICRISAT lines, and a space for a local check. This went to 14 locations.

Trial 2: Consisted of lines withdrawn from our populations and has been reported under population improvement. It was sent to 14 locations.

Trial 3: Contained 48 entries of Serere (Uganda) material (plus local check) and was sent to nine locations within 10^0 latitude of the equator.

Trial 4: Was a 24 + 1 check reduced version of Trial 1 for locations which could only handle smaller trials, and was sent to 19 locations.

In addition, two of the AICSIP trials were sent to a few selected locations.

Some extracts from the data received are given in Table 11. The AICSIP material (CSH, CSV, SPH, SPV) did well in many places. Material from Serere in Uganda (3DX, 5DX, 8DX, 9DX, 14-P and Kafinam crosses) also did well in the equatorial belt.

Trials on the ICRISAT Site

A range of material from all our projects was tested on low fertility red soil (20N: 9.0P), high fertility black soil (111N: 46.5P) in the kharif, and on high fertility (111N: 46.5P) in the rabi. Replications were also tested under heavy shoot-fly attack. In the kharif season, there were ten trials containing 2205 entries, of which 133 were carried forward for further trial. In the rabi season, there were 11 trials, containing 1532 entries. A few of the results illustrating performance are shown in Table 12. We believe that selecting under the contrasting conditions of kharif and rabi seasons should help to identify types with broad adaptation. The best entries from the rabi trial series have gone in to the 1976 international kharif trials throughout the SAT.

BREEDING (B) QUALITY

EARLINESS WITH MOULD RESISTANCE

Earliness and non-weathering lustrous grains resistant to grain moulds such as *Curvularia*, *Fusarium*, *Phoma* etc. are the main selection criteria in this breeding programme. In order to combine these characters with acceptable yield levels a crossing programme bringing in different component characters through several parents of diverse origin was undertaken. The following parents were used in these crosses:

Early (40-50 days to flower): 12 IS conversion lines from Puerto Rico, 18 IS numbers from the world collection.

Mould Tolerant: 23 Zera Zeras, CS 3541, 8272-1, M-35-1, IS 9333, 9327, and 9530.

High yielding: 12 from India, 2 from W. Africa, 3 from E. Africa, 3 from Egypt, and 3 elite entries from ICRISAT trials.

A total of 2250 single crosses, 341 double crosses and 175 three-way crosses were made this year. Most of the F_1 hybrids were grown in the rabi and approximately 60% of them were rejected based on subsequent information on the mould tolerance of the parents. The F_2 generation of the remaining crosses will be screened in the next kharif for grain mould

TABLE 11: EXTRACTS OF YIELD (Q/HA) FROM S[illegible] INTERNATIONAL TRIALS

(A)

Pedigree	Feni, Bangladesh	Serere Uganda	Yei, Sudan	Yousafwalla, Pakistan	Laguna, Philippines
Kafinam x Lulu	27	40	27	27	12
Kafinam x SB 65	-	36	28	-	35
Kafinam x Simila	36	31	32	26	37
IS 858	30	30	14	17	-
14-P-3-2-1	-	29	13	-	35
CSH-1	26	20	14	35	-
CSH-5	13	16	11	57	13
CSH-6	21	16	27	52	-
CSV 3	8	23	6	32	3
CSV 4	5	21	17	12	6
CSV 6	6	14	9	24	-
Local check	24	21	20	22	24

(B)

Pedigree	Bambey, Senegal	Saria, Upper Volta
CSV 1	20	41
CSV 2	22	28
CSV 4	23	41
CSV 5	20	46
SPV 9	13	47
SPV 13	14	45
SPV 35	20	47
SPV 58	30	31
CSH 1	37	43
CSH 5	12	64
Local check	40	43

(C)

Pedigree	B[redacted] Senegal	[redacted]aria, Upper Volta
CSH 5	23	58
CSH 6	45	65
SPH 1	35	52
SPH 2	38	46
SPH 4	29	55
SPH 6	35	46
SPH 10	41	59
SPH 21	15	54
SPH 24	34	57
MSH 31	23	53
22E	40	51
Local check	43	40

(D)

Pedigree	Khon Kaen, Thailand	Farm [illegible]wam, Thailand	Laguna, Philippines
Serena	47	38	18
Dobbs	27	28	36
3DX 57/14/4	46	39	21
5DX 36/1/2	34	24	30
5DX 61/6/2	43	30	21
5DX 136/1/2/1	34	30	23
5DX 142/4	41	32	11
6DX 2/2/4	37	34	23
9DX 2/3/2	45	36	17
9DX 6/F_5/30	42	30	10
9DX 9/F_5/11	39	32	6
Local check	29	27	20

TABLE 12: DATA FOR BEST ENTRIES FROM 75K AND 75R TRIALS AT PATANCHERU

Pedigree	Days to flo-wer (Kha-rif)	Plant hei-ght (cm)	Yield (q/ha) Kha-rif high ferti-lity (111N, 46.5P)	Kha-rif low ferti-lity 20N, 9.0P)	Rabi high ferti-lity (111N, 46.5P)	Com-bined	100 seed wt. (g)	Shoot-fly (% dead hearts)
Diallel 918 x PP3	64	200	66	14	80	53	2.46	55
Diallel 7469	71	205	55	34	63	51	2.80	50
Bulk Y x EC 64376	64	200	53	23	73	50	2.73	25
Indian x exotic 8465	65	195	65	16	68	50	3.13	54
Pickett-4-8	66	180	63	18	53	45	2.69	69
W. African x Nigerian	64	190	47	9	72	43	2.80	44
Diallel 1008	69	165	33	24	72	43	2.18	25
Diallel 15683	70	205	58	24	43	42	-	33
EN 3355	61	185	54	21	49	41	-	29
PP6	57	150	45	14	62	40	-	20
Pickett-3	69	153	46	22	45	38	2.25	39
Diallel 1031	57	165	55	13	46	38	2.70	39
Diallel 848	59	165	51	10	53	38	-	30
Diallel 910	64	160	47	11	48	35	2.42	21
Bulk Y x Pickett-4-8	64	130	31	19	49	33	3.49	50
CSV-3 (370) (a)	64	170	63	30	36	43	2.20	57
CSH-1 (b)	60	170	68	40	93	67	2.72	44

(a) Control variety

(b) Control hybrid

resistance, earliness and good grain quality. All the single crosses and double crosses were used as pollen parents on early good grain male-steriles (ms_3 and ms_7) in adapted backgrounds, and from this a composite population will be developed. Some 130 single cross F_2s were planted in the summer nursery, but selection was limited to earliness, good grain quality and important agronomic characters as no grain moulds developed. Selections from 75 F_2 crosses totalled 2,500. The F_3 progenies will be screened in the next kharif for grain mould resistance.

Two generations of selfing and selection in random mating populations and in segregating crosses between populations and elite varieties resulted in 454 good grain early types (40-50 days to flower) being selected in Kharif 1975. These were grown in the rabi, and 235 were selected for yield trials in Kharif 1976. Many of the very early sorghums suffer from poor grain qualities. To improve the grain quality of such early lines, we crossed them to several late lines having high seed weight, and hard lustrous large grains. Selection for photoinsensitivity, earliness and good grain quality components in the F_2 and F_3 generations resulted in 135 early lines with large corneous, lustrous grains.

The mould resistance composite from Nigeria was random mated and 426 good steriles were selected.

Large Glumes

Straw coloured and free threshing large papery glumes give the grains some production against weathering and mould damage, particularly in the early stages of grain development. The value of this character is being tested by transferring large glumes to early, photoinsensitive backgrounds and testing the resultant early large glume types in the rainy season both under natural and artificial mould environment. Several early and adapted lines have been crossed to 35 large glume photosensitive parents. Some 286 single crosses, 26 double crosses and 25 F_2 hybrids were grown in the kharif. Half of the F_1 material failed to head, but 170 early and large glume selections were taken in the F_2 generation of the remainder. The F_3 generation was planted in the rabi and 100 lines were selected for grain mould and yield testing in the kharif. Other F_2s were grown in the summer nursery, and 450 early plants with large glumes for similar testing.

Recurrent selection in a random mating population should be a good method for improving the glume coverage of the grain. Genetic male sterility has been incorporated in the large glume parents by crossing them to early male steriles (ms_3 and ms_7). Early large glume male steriles segregating in the F_2 have been sibbed with early large glume fertiles. A population with a high level of out-crossing (large glumes limit the level of out-crossing) is thus being composited, and the gl coverage of the grain will be improved through recurrent mass selection.

GRAIN QUALITY IMPROVEMENT

Evident Quality

A population composed of sorghums with good evident grain quality is being developed. We still lack understanding on what grain quality really is, so are assessing for colour, plumpness, lustre, proportion of corneous endosperm, and hardness. The population is being made from a wide range of genetic backgrounds, crossed on to male-steriles in small groups, the groups themselves being re-randomised every season. The pollinator lines are subjected to selection each generation, and are kept as advanced generation progenies until their quality can be assessed. The F_1's of the crosses are also assessed. Selection and crossing to male-steriles was continued in this population for both Kharif and Rabi 1975, and yield trials of 161 pollinators and 73 crosses have been prepared for Kharif 1976 planting.

Crosses were made to initiate side-cars for large grain, local high quality grain, and high lysine grain. Sixteen samples of 2 kg. each of a range of high quality types were taken to CFTRI for preliminary assessment, which we hope will be the beginning of co-operative activities leading to a proper understanding of the quality requirements for sorghum as a food, and possibly, the development of simple, small scale tests to identify the best quality types. RY 49 from Ethiopia, which has a wheat-like flavour, was included, as well as the medium lysine mutant P721. Twelve sorghums were received from Lucknow, which may contain types with a grain scent similar to that of Basmati in rice.

Segregates from RY 49 crosses were backcrossed to RY 49, in order to convert it to photoinsensitivity and to reduce plant height, as it is a difficult plant to handle at Patancheru.

Nutritional Quality

Plantings in Kharif 1975 contained 137 photoinsensitive high lysine selections, from the original Purdue crosses: 113 selections from plump opaque intercrosses: 693 selections from crosses of Serere Populations x Ethiopian hl, and 190 newly received selections from Purdue. Some head rows of P 721 were also grown, and although showing good agronomic characters, this variety exhibited some pollen sterility. Selections were taken, and some 3,000 were analysed for protein, using the Technicon analyser, and for UDY value, based on 80 mg. of protein.

Three groups of the selections were chosen for combining into populations. Group A, with very high UDY values per 80 mg. of protein (39+) contained selections from seven lines: Group B, UDY value of 30-38.5, contained selections from 28 lines: and Group C, consisting of the model UDY values 28-29.5, contained selections from 25 lines. P721 selections were added to each of these groups, and within group intercrossing, using the segregating male-steriles, was begun at Bhavanisagar in the summer. In Rabi 1975, selections from the same kharif planting were grown as four groups, (1) High UDY low protein (25 lines), (2) High UDY high protein (8 lines), (3) Low UDY low protein (6 lines) and (4) Low UDY high protein (16 lines).

Laboratory analyses are not yet available for most of this material, but sufficient are in to show that large fluctuations in protein levels are being found from season to season as illustrated by the following figures:

Entry	1974 Rabi			1975 Kharif			1975 Rabi		
	Protein	UDY[(a)]	N[(b)]	Protein	UDY	N	Protein	UDY	N
79337-2	7.2	30.0	1	7.8	34	1	12.0	24.5	20
79339-3	7.1	30.5	1	7.9	28	1	13.5	24.5	6
79337-4	7.2	31.5	1	7.2	28	1	12.7	23.0	8
79751-4	7.6	30.0	1	7.8	30	1	15.1	25.5	6
79337-2	7.2	30.0	1	7.0	32	1	13.6	23.5	6
79339-3	7.1	30.5	1	7.5	31.5	1	12.0	23.0	4

[(a)]Per 80 mg. Protein [(b)]No. of entries used to calculate the mean

Similar results were obtained from some of the Kharif 1975 selections many of which had been selected as low protein high UDY in the 1974 Rabi, but from the kharif harvest showed high protein with reduced lysine. The differences are large, and too consistent to be simply due to error. The only possibility which occurs to us is that the hl gene is a prolamine suppressor, which breaks down or losses penetrance, or mutates back to normal, rather readily when not in the shrunken endosperm background.

BREEDING (C) MISCELLANEOUS

GRAIN-GRASS SORGHUMS

Grain-grass sorghums may be valuable in difficult irregular rainfall areas. They are drought resistant, ratoon well and mature in some 70-75 days. They may also be useful in rabi areas where the sorghum grows on residual soil moisture, especially as their maturity length is not much affected by cold.

Large number of crosses were made between grain-grass and normal sorghums showing resistance to pests and diseases, good grain quality, and good yield. F_1s were grown in Coimbatore during Summer 1975. These were intercrossed, back-crossed to new grain-grass lines obtained from Purdue and Texas, and also selfed. In the F_2 segregating material very good segregants appeared which resembled the grain-grass parents with improved plant-type and excellent grain quality. Double and back-crosses have been used to pollinate genetic steriles to develop a random mating population.

A second series of crosses was made between adapted, pest and disease resistant normal lines and grain-grass lines received from Purdue in late 1974 R. F_1s were grown in 1975 K and F_2s in 1975 R. The F_1s were also crossed onto steriles.

The Rabi 1975 cold night temperatures had little effect on flowering date or growth of the grain-grass material, but favoured profuse tillering. We selected 1173 early plants and grew them at Bhavanisagar in Summer 1976. A second series of selections was made two weeks later, and those were grouped into five classes - Class I, big grassy types and Class V, normal sorghum. The number of selections falling into each class was as follows:

	Class					
	I	II	III	IV	V	Total
Bhavanisagar, 1976 S	580	525	68	-	-	1173
Patancheru, 1975 K	97	328	389	146	14	974

Additional selections were also made in double crosses, back-crosses, and F_2's and crosses were made with recently identified shoot-fly, midge, stem-borer, and mould resistant lines. Genetic steriles were pollinated with good F_3 selections. Some 380 families were selected at Bhavanisagar as F_4 derived lines. Some outstanding individual plant selections were also kept.

Five grain-grass lines were tested for drought resistance by the physiologists in Rabi 1975. These showed very effective drought avoidance.

TETRAPLOID GRAIN SORGHUM

Crosses made between photosensitive Serere tetraploid bulks and photoinsensitive Ross 4N from Nebraska gave good segregants in F_2. Selections from this group were planted in Kharif 1975. There was little segregation for earliness, the range of days to flowering being 61-86.

Selections were made for the evident grain quality characters large grain, white colour, thin pericarp, and corneous endosperm. These were planted in Kharif 1975, at two planting dates. They showed only slight photoperiod sensitivity, and 120 selections were taken. Selections for the yield components number of branches, number of nodes, and number of grains per branch were also made. Ross 4N selections exhibited a wide range of variability in flowering date, height and head characters, and 232 individual plant selections were made. Eleven short fertiles and 52 photoinsensitive steriles were chosen as a good source of ms_3 genetic sterility at the tetraploid level.

In order to introduce *Sorghum halepense* germplasm into the tetraploids, 110 crosses were made with a type from Pantnagar, and 86 crosses with another from Bangkok. F_1s were planted in Rabi 1975, and they resembled the wild parents in all the morphological characters. One back-cross was made to an improved cultivated tetraploid. One or two more back-crosses may be necessary to get rid of undesirable wild characters.

Some tetraploid plants reverted back to the diploid, and these polyhaploids are being used to transfer *Sorghum almum* genes into good adapted diploids, 450 such crosses being made.

The good grain quality diploids 148, 22E, 2219B, SC 423 74R 24/1-52, 74R 24/1-7, and 74R 23 (2-50), were successfully made auto-tetraploid with colchicine.

GERMPLASM

COLLECTION AND MAINTENANCE

A total of 14240 accessions is available in the ICRISAT sorghum germplasm bank, consisting of 11778 lines covered by I.S. numbers and 2462 accessions yet to be numbered by ICRISAT (Table 13). Some of the I.S. numbers in the world collection available from Rajendranagar appeared to have lost their identity, so a second set was brought from Purdue University, corresponding IS numbers were sown side by side, and checked for correct identity. 10678 IS entries from

TABLE 13: SORGHUM GERMPLASM ACCESSIONS AT ICRISAT (31-5-1976)

A) Collections covered by IS Numbers:

1. AICSIP & PURDUE sets	11622
2. USDA, Washington	25
3. Few seeded lines (nursery)	131
	11778

B) Collections not covered by IS Numbers:

1. NES & NSS numbers from USDA, Washington *	187
2. Ethiopian collections	1083
3. Ethiopian Market Collections (sent by C.J.P. Seegeler, Holland)	52
4. Nigerian collection	24
*5. Samples from Yemen brought by D.L. Oswalt	23
*6. Farmers types from Andhra Pradesh	147
7. Farmers types from North Ghana	52
8. Named cultivars	349
*9. Named cultivars (recent collection)	29
10. Genetic stock collection	
i) Quality lines	6
ii) Insect resistant lines	122
iii) Disease resistant lines	47
iv) Striga resistant lines	14
v) Cytoplasmic A&B lines (93 x 2)	186
vi) I.S. conversion lines	127
*vii) Scented sorghum from Lucknow	12
viii) Grass grains	2
	2462

* Recently added, yet to be planted and multiplied

Purdue were planted, and 1100 gave no germination. Corresponding figures for the ICRISAT IS entries were 9219 & 8. Seeds were sown in red soil (2 ha) and black soil (4 ha) on 27 and 29 November, 1975 in 2.25 m rows with a spacing of 75 cm x 15 cm. Highly photosensitive lines from guinea, caudatum and durra groups did not flower. For many of these lines remnant seed was available in the store, but for about 150 lines where there was no remnant seed, so plants were transplanted to the nursery. All the collctions were maintained by selfing 5-10 representative heads in each line.

NEW COLLECTIONS

Mr. K.E. Prasada Rao toured the important rabi sorghum areas of Andhra Pradesh and collected 147 farmer's types and interestingly four of them were found to contain shoot-fly resistance besides good quality grain. In addition a number of accessions were received (Table 14). The cooperation of these donors is gratefully acknowledged.

TABLE 14: SORGHUM GERMPLASM LINES RECEIVED IN 1975-76

Donor	Country	Number	Description
1. Asst. Plant Breeder, Surat	India		Farmer's types
2. Sorghum Breeder, Indore	India	1	Farmer's type
3. W.R.O. Oxford	U.K.	2	Striga resistant lines
4. Brought by D.J. Andrews	Sudan	1	Striga resistant line
5. Sorghum Breeder, Parbhani	India	55	Named cultivars
		8	Sweet sorghums
6. Sorghum Breeder, APAU	India	23	Named cultivars
7. Dr. N.G.P. Rao	India	9	Named cultivars
8. Sorghum Breeders, Tamilnadu	India	6	Named cultivars
9. Sorghum Breeders, Akola	India	11	Named cultivars
10. Sorghum Breeder, Dharwar	India	5	Named cultivars
11. Sorghum Breeder, Mohol	India	6	Striga resistant lines
12. Dr. Jotwani, IARI	India	3	Midge resistant lines
13. Brought by L.J.G. van der Maesen	Turkey	1	Farmer's type
14. Brought by A.H.Kassam	Nigeria	8	Farmer's types
15. Economic Botanist, Lucknow	India	12	Scented sorghums
16. Brought by D.L. Oswalt	Yemen	23	Farmer's types
17. Dr. R.S. Paroda, Hissar	India	2	Wild sorghums

EVALUATION

All the 14240 accessions except the 211 received very recently were evaluated for the morphological characters: plant height, days to 50% flowering, awning, midrib colour, plant pigmentation, tillering, peduncle exertion, earhead length and breadth, panicle type, glume colour and covering, grain colour and 100 seed weight, threshability, lustre, presence of subcoat, endosperm texture and type.

SCREENING FOR INSECT, DISEASE, STRIGA AND DROUGHT RESISTANCE

The following are the details of the accessions screened:

S.No.	Screened for	No. of accessions	Descriptive
1.	Disease resistance	5183	Pathology Unit
2.	Insect resistance	486	Entomology Unit
3.	Striga resistance	153	Sorghum breeding
4.	Drought resistance	50	Physiology Unit

In addition 800 accessions were supplied to sorghum breeding for utilizing in various projects.

DOCUMENTATION AND PUBLISHING EVALUATION

A pilot catalogue has been prepared with the data collection of a sample of 300 accessions grown in 1974 Rabi. The Taximetric laboratory of Colorado University carried out the printing after computer treatment of the data. Data were tabulated for the remaining accessions also and are being sent to Colorado for the preparation of a catalogue.

SEED DISTRIBUTION

Requests for 51 consignments of germplasm involving 2954 samples from Scientists in India and elsewhere were met.

CLASSIFICATION

The applicability of various classification systems was tested, and the world collection is being classified according to Harlan's and de Wet's system. Panicle branches of all entries are being preserved as reference samples.

ENTOMOLOGY

GENERAL

Considerable progress was made on the general entomology of the cereal crops, investigation of the bionomics of the three main pest species - sorghum shoot-fly, *Atherigona soccata*, stem borer, *Chilo partellus* and sorghum midge, *Contarinia sorghicola*, and screening of sorghum cultivars for resistance/tolerance to sorghum shoot-fly.

SHOOT-FLY BIOLOGY

Breeding work over several seasons confirmed that *A. soccata* was dominant in the crop at Patancheru. Over 95% of the flies bred from sorghum were of this species. *A. eriochloae* was recovered from ratooning sorghum tillers for a limited period in December 1975 (Table 15). *A. soccata* was also recorded from maize, pearl millet, *Echinochloa colonum*, *Eriochloa procera*, *Cymbopogon* sp., and *Paspalum scrobiculatum*. A wide range of other *Atherigona* species was reared from various cereals and grasses during the year (Table 16). *A. falcata* was dominant in grasses. *A. approximata* was common, but not damaging in *Pennisetum typhoides*.

TABLE 15: SPECIES OF *ATHERIGONA* BRED FROM SEEDLINGS OF A RANGE OF SORGHUM CULTIVARS IN THE PERIOD 5.9.1974 - 7.12.1975

Flies			Species of male flies				
Total	Male	Female	*soccata*	*orientalis*	*approximata*	*eriochloae*	others
1585	562	1023	548	2	1	7	4

Good progress was made on development of an attractant for sampling shoot-fly populations. The attractivity of fish meal was enhanced by the addition of ammonium sulphide and Brewer's yeast (Table 17). Catches with unsupplemented fish meal were greatest 3-4 days from admixture of the attractant and water (Table 18). In

TABLE 16: HOST PLANTS AND *ATHERIGONA* SP. RECORDS FROM PATANCHERU, HYDERABAD, INDIA

	Total	male	Species of *Atherigona*: *soccata*	*approximata*	*falcata*	*oryzae*	*orientalis*	*pulla*	*eriochloae*	*milliaceae*	*laeta*	*punctata*	spp
Zea mays Linn.	5	5	2		1		1					1	
Pennisetum typhoides Stapf and Hubb	90	28	7	21									
Eleusine coracana Gaertn.	1	1								1			
Panicum miliaceum Linn.	3	1						1					
Panicum psilopodium Trin.	168	67			1			66					
Cynodon dactylon Pers.	8	3									1		2(a)
Dactyloctenium aegyptium P. Beauv	6	2											2(b)
Digitaria adscendens (HBK) var *criniformis* Henr.	189	81			1	80							
Echinochloa colonum Link	223	90	3		82	3		2					
Echinochloa crusgalli P. Beauv	47	22			19			3					
Ischaemum pilosum Wight	1	1			1								
Chloris barbata Sw.	4	1			1								
Eragrostis cilianensis Vignolo-Lutati	1	1						.				1	
Eriochloa procera C.E.Hubb	58	17	2		2			1	3			9	
Cymbopogan sp.	1	1	1										
Setaria italica P.Beauv	1	1		1									
Paspalum scrobiculatum Linn.	2	2	2										
Unidentified grass	78	26			24	2							
Unidentified grass	20	8			8								

(a) *A. reversura* ssp. nov. and *A. sp.* nov.
(b) *A. atripalpis*

TABLE 17: CATCHES OF *ATHERIGONA* SP. MAINLY *A. SOCCATA* WITH DIFFERENT ATTRACTANT TREATMENTS

Treatment	Mean number of flies caught	
	Experiment 1	Experiment 2
Water control	4.0	2.4
Fish meal	113.3	96.8
Brewer's yeast	-	4.0
Ammonium sulphide	-	4.0
A. sulphide + fish meal	-	43.5
Brewer's yeast + fish meal	-	97.4
A. sulphide + brewer's yeast	-	178.1
A. sulphide + brewer's yeast + fish meal	-	241.8
L.S.D.	58.08 (504)	184.21 (1404)

TABLE 18: CATCHES OF *ATHERIGONA* SPECIES, MAINLY *A. SOCCATA* BY DAY, FISH MEAL ATTRACTANT

	Mean number of flies caught	
	Experiment 3*	Experiment 4**
	29.0	45.5
	49.5	136.7
	57.9	99.9
	100.5	120.9
	43.8	72.9
	81.3	63.5
	48.5	47.1
L.S.D.	56.2 (58df)	64.36 (96df)

* 1 day units ** 2 day units

preliminary trials catches per day from the better treatments averaged 120 per trap over a two-week period. Identification of species trapped in sorghum fields indicated a preponderance of A. *soccata* (over 90%). A. *orientalis* and A. *falcata* were also commonly trapped. This information was useful confirmation of breeding records (see above). The reasons why catch is maximised at 3-4 days, and the chemical constituents involved in attractivity, are being studied. Skatole has been shown to be an effective short-term attractant, but addition of fertilizers or ammonia had a detrimental effect on effectiveness of fishmeal/ammonium sulphide/Brewer's yeast mixtures. Addition of sorghum dead hearts to water gave significant catches of shoot-fly.

Oviposition/behavioural studies were begun. Preliminary results were in line with Soto's unpublished data indicating that fecundity of females was considerably increased by feeding Brewer's yeast. Studies on oviposition at differing plant spacings showed that the maximum numbers of eggs were laid at close spacings, however, the maximum percentage plants attacked was obtained at spacings between 10 and 20 cm (Table 19). This indicates that screening should be carried out at 20 cm interplant for maximum efficiency, while interlards should be sown at around 1 cm to maximise shoot-fly build up. Attempts to obtain aestivating pupae of A. *soccata* were unsuccessful.

TABLE 19: EFFECT OF INTERROW PLANT SPACING ON SHOOT-FLY OVIPOSITION AT SITES, PATANCHERU, 1975

	Mean number and percentage plants with eggs					
	Site 1		Site 2		Site 3	
	No.	%	No.	%	No.	%
1.0 cm	217	60.7	247	48.1	234	35.3
2.5 cm	159	67.7	202	67.6	148	54.9
5.0 cm	113	74.7	114	78.9	100	76.8
10.0 cm	59	78.2	45	78 4	45	76.4
20.0 cm	39	79.4	32	85.4	32	88.0
S.E ±	10.1	3.90	10.9	4.02	9.3	2.91
P	0.001	0.05	0.001	0.001	0.001	0.001

SCREENING FOR SHOOT-FLY RESISTANCE

A very large amount of sorghum germplasm was screened over the three seasons covered by this report. This included lines recorded as being resistant in reports from AICSIP or from West

Africa, and previously unscreened lines from the world collection. New accessions collected by the germplasm botanists from farmers' fields were tested. Much of the material in the breeders' populations was rated for susceptibility. In all instances Starks' interlard/fish meal technique was used and satisfactory levels of oviposition achieved.

Lines selected as showing marked oviposition non-preference to shoot-fly included IS 4664, 2138, 4506, 2201, 2122, 2269, 2312, 2146, 5656, 5383 and 1082. Several of the West African/Indian crosses, e.g. IS 5604 x 23/2, IS 5604 x 453 and IS 5383 x 453 showed marked non-preference. Some antibiosis was possibly present in some other lines in which IS material had been crossed to WABC. This is being followed up. In all, in the period about 10 ha. of screening was effected representing over 15,000 lines.

Several lines showing non-preference have been studied in detail in collaboration with the Cereal Physiology Unit and COPR to attempt to elucidate the reasons for lower egg numbers. Preliminary information suggests some relationship between trichome number on the underleaf surface and egg number. Conventional and stereo microscopy are being used to confirm these preliminary data. Behavioural studies also indicate that chemoreception may be involved in selection of oviposition site.

STEM BORER BIOLOGY

Progress was made on developing a suitable medium for rearing *Chilo partellus* in large numbers for screening work. Counts of damage under natural *Chilo* attack were taken on lines under screening for shoot-fly.

Detailed studies of *Chilo* carry-over in stalks of various cultivars were continued. 11% of the larvae collected in December 1974 did not pupate until late June 1975. Parasitism rates were high. Identified parasites included *Sturmiopsis inferens* Tns., *Halidaya luteicornis* Walk., *Carcelia* sp., *Bracon chinensis* Szepl. and *Xanthopimpla stemmator* Thun.

Experiments on 'carry-over' again indicate that a significant proportion of the stalks of all cultivars at ICRISAT carry *Chilo* at the start of the season, however, regular sampling of stalks from farmers' fields in March-May, 1976, failed to locate the insect (Table 20).

Testing of the synthetic pheromones of *Chilo* recently synthesised by Dr. B. Nesbitt of TPI, London, was initiated. Considerable success was achieved. Various trap designs were tested and a square pan trap with a lid adopted. In initial trials, the high titre vials (cp 75/20) caught more moths than the low titre (cp 75/19) and there was a rapid drop off of efficiency after 4 days. There was a strong indication, subsequently repeated regularly, that catches were highest after rain. More moths were caught at crop height than on top of 6' bunds or at ground level. Subsequent trials in which tests were carried out in which high titre vials were compared with vials containing the major and minor components in natural proportions, and the major and minor components in separate vials suspended in the same trap indicated that utilising the pheromones in separate vials was more efficient. Vials were not efficient after 16 days. Catches using virgin female *Chilo* were disappointingly low; and the minor component used alone caught no moths.

TABLE 20: SUMMARIES OF OBSERVATIONS OF *CHILO PARTELLUS* ON STOOKED SORGHUM MATERIAL - 1975-76

Name of the cultivar	Date of observation	No. of stalks sampled	Total No. of larvae	pupae		Parasited pupae	
				alive	cases	alive	cases
CSH-1	5.12.75	200	35	-	7	-	8
Swarna	5.12.75	200	29	-	4	-	6
Local	5.12.75	100	15	-	5	-	1
CSH-1	5.1.76	200	20	1	12	-	13
Swarna	5.1.76	201	15	-	4	2	10
Local	4.1.76	101	21	-	2	-	3
Formers' Field	4.1.76	100	14	-	1	-	1
CSH-1	6.2.76	125	20	3	7	3	5
Swarna	6.2.76	200	20	5	21	-	6
Local	6.2.76	104	16	1	7	-	3
Farmers' Field	6.2.76	100	6	1	3	-	4
CSH-1	5.3.76	200	10	4	10	4	12
Swarna	5.3.76	200	3	3	15	2	3
Local	5.3.76	100	2	1	5	1	2
Farmers' Field	5.3.76	100	Nil	1	2	-	1
CSH-1	5.4.76	200	8	-	21	1	8
Swarna	5.4.76	200	2	3	4	1	13
Local	5.4.76	100	2	-	7	-	3
Farmers' Field	5.4.76	100	Nil	-	-	-	1

Light trap records of *Chilo* are being maintained and these will be compared with data obtained from pheromone traps. Indications are that a low level of moth activity is present throughout the year. However, peaks of activity occurred in August-September and this year, possibly owing to unseasonal showers, in April/May. Population levels were relatively low in December, January and February.

MIDGE

Preliminary data only has been obtained on midge. Several parasites have been identified including *Eupelmus popa* Gir., *Apanteles* sp. and *Tetrastichus* sp. In general, midge attack at Patancheru is low and screening for midge resistance will have to be carried out elsewhere. Experiments carried out on midge emergence show that this occurs just before day break in the April-May period, peak emergence was recorded between 3 a.m. and 5 a.m.

PATHOLOGY

IDENTIFICATION OF RESISTANCE TO GRAIN MOULDS

A total of 4036 germplasm and breeding lines were screened for resistance to grain moulds in the field during Kharif 1975. The entries were confined to those with white, yellow, dull yellow or light red grains. Five heads from each line were inoculated with *Fusarium*, *Curvularia* and a mixture of both. Inoculum was prepared by growing isolates of these fungi on autoclaved sorghum grain. The extended rains provided an excellent environment for this test and considerable natural mould development occurred on uninoculated heads of highly susceptible lines. Thus the lines received a severe test for grain mould reaction. The lines were scored on a 1-9 scale (1 no mould and 9 completely moulded). Three lines only (IS-9327, IS-9333, IS-9530) showed a 1 reaction and 90 lines were in reaction category 3. A summary of the numbers of entries in the various reaction categories is given in Table 21. The proportion of lines in categories 7 and 9 are greater in the inoculated heads indicating the usefulness of the inoculations even under conditions suitable for natural mould development.

During Rabi 1975 five head-rows were planted for all 93 lines in reaction categories 1 and 3 from the kharif trial, in an attempt to retest their mould reactions and to multiply seed. Heads were again inoculated with the fungal isolates used in the kharif trial and immediately after inoculation the heads were covered with white paper bags over polyethylene bags to maintain humidity around the developing grains. There was poor seed set on bagged heads in this trial which was probably related to high temperatures developing within the bags. Despite the poor seed set it was possible to observe differences between the inoculated heads of the known high-susceptible checks and the test lines, which again appeared less susceptible. Non-inoculated heads of all lines were entirely free from moulds.

TABLE 21: THE NUMBERS OF LINES SHOWING VARIOUS GRAIN MOULD REACTION CATEGORIES IN THE GERMPLASM SCREEING K-1975

Inoculum	Disease reaction category *				
	1	3 **	5	7	9
Fusarium	3	178	1598	2039	218
Curvularia	3	254	1924	1795	60
Bagged non-inoculated	3	319	2326	1397	11
Non-treated	3	357	2345	1324	7

* 1 = no mould, 9 = severe mould over entire head
** 90 lines were common to all treatments.

MICROFLORAL & SEED TREATMENT STUDIES ON KHARIF HARVESTED GRAIN

Seed of CS-3541 harvest from the Kharif 1975 crop was divided into visually clean and moulded samples. The viability, microfloral infection, and the effects of treating with four fungicides each at three levels were then tested. Results are summarized as follows:

Treatment	Apparently clean grain		Mouldy grain	
	% germination	% fungal infection	% germination	% fungal infection
None	20		4	98
Agrosan 1%	30	56	4	59
Demosan 1%	28	84	1	99
Thiran 1%	33	40	8	57
Benlate 1%	29	15	2	18

None of the fungicides used at 0.2% or 0.5% improved germination over the control, but Benlate reduced fungal infection substantially at all levels. The fungi predominating on the "clean" grain were *Fusarium*, *Olpitrichum*, and *Tricothecium*, and on the mouldy grain *Fusarium*, *Curvularia*, and *Olpitrichum*. The degree of infection of the clean grain is surprising, and needs further analysis, particularly as some species of *Fusarium* produce powerful mammaliotoxic mycotoxins.

LEAF DISEASE & DOWNY MILDEW SCREENING

It would be valuable to be able to screen the breeders' materials for resistance to Sorghum Downy Mildew (SDM) and to the major leaf diseases. During the kharif season, various lines developed high incidence of grey leaf spot, zonate leaf spot, and sooty stripe, and 100% SDM infection was achieved on two susceptible varieties in garden plots. It therefore seems possible that screening for resistance to SDM and some leaf diseases, using infector lines (spreader rows) may be practicable. Results of similar attempts in the rabi and summer seasons were discouraging.

INTERNATIONAL SORGHUM DISEASE RESISTANCE TESTING PROGRAMME

This programme has been developed in consultation with AICSIP, Texas A & M, and the W. African OAU/STRC JP 26 Project. Three nurseries have been distributed to locations in the SAT for planting in Kharif 1976, as follows:

Trial	No. of entries	No. of locations
1. Grain Mould Nursery (ISGMN)	55	12
2. Leaf Disease Nursery (ISLDN)	60	9
3. Downy Mildew Nursery (ISDMN)	35	7

PHYSIOLOGY

GENERAL

Four groups of physiological attributes must operate in an appropriate balance to provide the best possible adaptation for growth and consistent yield. These relate to (1) high rate of production of dry matter per unit area per unit of production resource, and efficient distribution of carbohydrate (2) production of high seed number per unit area and high grain filling rate, (3) nutrient uptake and distribution to support the superior carbohydrate supply and distribution in (1) and (2) above, and (4) ability to endure drought stress (i.e. the ability of all the attributes in (1), (2) and (3) above to contribute efficiently towards yield production under water stress). For all these attributes there is a wide range in genetic variability and genotype x environment interaction. We have attempted to assess some of this variability in relation to yield and to understand the associations which exist between attributes. We hope to identify source materials with superior carbohydrate source and/or sink attributes, superior nitrogen uptake and distribution, and superior drought resistance, and utilize them for genetic improvement.

VARIABILITY IN GS1, GS2 AND GS3

A variability study on attributes in GS1 (vegetative phase), GS2 (head development phase) and GS3 (grain filling phase) on 49 genotypes was made. The length of GS1 varied from 30 to 41 days (mean for all genotypes: 32.8 days), number of leaves produced varied from 8.3 to 10.2 (9.4), and the rate of leaf production varied from 3.0 to 4.6 days per leaf (3.3). The length of GS2 varied from 31 to 64 days (42.5), number of leaves produced varied from 2.2 to 10.8 (6.2), and the rate of leaf production varied from 4.6 to 14.3 days per leaf (5.0). The position of the largest leaf from the top varied from 2.0 to 5.8 (3.5), corresponding to a variability of 0-6.3 (2.6) leaf positions between the position of the largest leaf and the leaf expanded at the time of panicle initiation. In other words, the node bearing the largest leaf was on average 2.6 nodes above the node which had a fully expanded leaf at panicle initiation. The length of GS3 varied from 31 to 56 days (47.2). Grain yield varied from 2,560-9,940 kg/ha (5,440), corresponding to a variation in yield produced per day per season of 20.6 to 72.9 kg/ha (44.3), and yield per day in GS3 of 58.6 to 273.4 kg/ha (118.7). Seed number per head varied from 469 to 2,161 (1,287). Number of seeds per head produced per day in GS2 varied from 10.0 to 61.7 (30.4). Seed size varied from 24.0 to 54.6 g per 1,000 seeds (36.6). Grain filling rate in GS3 varied from 5.3 to 13.5 g per 1,000 seeds per day (10.6). Number of nodes per head varied from 5.3 to 13.5 (10.6). Number of branches per head varied from 29.8 to 92.0 (54.6). Number of branches per node varied from 3.6 to 8.0 (5.2). Number of seeds per branch varied from 8.8 to 62.6 (24.7). Number of seeds per node varied from 51.3 to 232.4 (322.4). Total dry weight produced varied from 7,260 to 32,000 kg/ha (14,750), corresponding to a variation in seasonal growth rate of 61 to 248 kg per ha per day (119). Grain as a percentage of total dry weight of above grounds parts varied from 16.4 to 55.7% (41.5). The analysis of associations between the above variables is in progress.

Analysis of data on leaf area, leaf position, seed number and grain filling collected from another experiment involving 76 genotypes has shown that the position of the largest leaf and its area was related to seed number per head and rate of filling of individual grains. Highest seed number per head within the maturity class 110-120 days was achieved when the position of the largest leaf was in the range 3-6 from the top. To obtain about 1,000 seeds per head at plant population of 10 per m^2, the leaf area of the largest leaf had to be about 200 cm^2; for 2,000 seeds per head or more, the largest leaf had to be about 400 cm^2 or more. Generally, the larger the leaf area of the largest leaf, the larger was the total leaf area of the leaves above the largest leaf, thus contributing to a rapid rate of grain filling. The position of the largest leaf was related to the total number of leaves and the range 3-6 corresponded to total leaf number range 12-16.

NITROGEN UPTAKE AND DISTRIBUTION

40 entries from elite selections were studied to define the range in variability in nitrogen uptake and distribution, and the possible influences on yield. The absolute amount of nitrogen in the grain at anthesis is only a small proportion of the total plant nitrogen, while under medium fertility level the amount in the grain at harvest consists largely of nitrogen transferred from the vegetative parts. The ratio of grain nitrogen to total nitrogen expressed as per cent can therefore be used to evaluate the nitrogen transfer efficiency (NTE) at different total uptake.

The total nitrogen uptake per plant varied from 0.22 g to 1.14 g, averaging 0.63 g. The NTE varied from 57.8% to 86.6%, and this difference was significant at $P = 0.05$ level. The mean NTE for all genotypes was 77.0% $\pm$ 0.29. However, at a given total uptake there were genotypes with NTE of more than 77.0%. For example, at total nitrogen uptake of 0.8 g/plant, NTE varied between 67.9% and 86.6%, suggesting a large scope for developing plant types with above average NTE. If the amount of plant nitrogen transferred to the grain varied only slightly, the grain yield would show a strong negative correlation with grain nitrogen and protein concentration. In the present study the proportion of plant nitrogen transferred to the grain at harvest varied significantly ($P = 0.05$). It is thus expected that the grain yield would show a weak negative correlation with grain nitrogen concentration ($r = -0.36^*$) as was found in the present study.

An increase in grain nitrogen content is expected to result in the decrease of nitrogen in leaves and stem. This was reflected in the negative associations between NTE and the nitrogen content of stover ($r = -0.54^{***}$), stem ($r = -0.46^{**}$) and leaves ($r = -0.55^{***}$). The grain nitrogen yield was positively related to the amount of nitrogen taken up ($r = 0.95^{***}$), nitrogen content of stover ($r = 0.45^{**}$), stem ($r = 0.36^*$) and leaves ($r = 0.31^*$). An increase in the grain nitrogen can therefore occur by an increase in the plant nitrogen. Grain nitrogen was strongly correlated ($r = 0.77^{***}$) with the total biomass. Therefore, the variation in plant size is likely to be associated with the variation in grain nitrogen content. Differences in grain nitrogen percentage of various genotypes were non-significant but differences among genotypes in the grain nitrogen content (Grain N% x Grain yield) were significantly different ($P = 0.05$).

NTE and Harvest Index were strongly positively correlated ($r = 0.83^{***}$) indicating that the achievement of a high harvest index requires a high NTE. The grain yield was positively correlated with the total plant nitrogen ($r = 0.51^{***}$), grain nitrogen content ($r = 0.58^{***}$) and NTE ($r = 0.33^{*}$). The negative significant correlation ($r = -0.36^{*}$) between grain yield and grain nitrogen percentage, was small enough to suggest that high yielding genotypes with a high grain nitrogen concentration could be obtained, provided genotypes were developed which had an above average nitrogen uptake, and which at a given yield could transfer the maximum portion of the nitrogen to the grain.

DROUGHT RESISTANCE

74 genotypes were evaluated in the field for their drought resistance response to a stress period of 30 days beginning at the panicle initiation stage. The material tested included 40 adapted genotypes and germplasm lines and 30 fertiles from the drought resistant population NP9BR. We found a wide range in the whole plant response to water stress. We have developed an evaluation procedure based on the effect of stress on the length of the growth cycle, absolute yield under stress, and decrease in yield under stress relative to the yield under no stress to enable the resistant genotypes to be grouped into two major response classes, i.e., avoidant and tolerant. For a genotype to be accepted as drought resistant we feel that it should be capable of producing a yield under experimental stress conditions of 2,000 kg/ha and/or have a relative yield reduction of no more than 30% compared to its yield under no stress. We consider that resistant genotypes with avoidant response are those whose growth cycle is either telescoped or not affected or extended by less than 7 days. These genotypes are able to grow during drought and complete their reproductive phase. Some of these genotypes have an ability to produce a 'second' yield from newly formed tillers during the post-stress period. The resistant genotypes with tolerant response are those whose growth cycle is extended by more than 7 days up to 30 days or more. These genotypes make some or no growth during the stress period and depend greatly or completely on post-stress recovery for producing a yield. We feel that the evaluation system must take into account the effect of stress on the length of the growth cycle. This will enable us to develop avoidant genotypes required in areas where rainfall is low and duration of the growing season limited

with little or no opportunity for post-stress recovery, and tolerant genotypes for areas where due to longer growing season, time is available for post-stress recovery after a mid-season drought.

SEEDLING, ROOT AND PANICLE DEVELOPMENT

78 genotypes were studied in petri dish, pot and field. The initial dry weight of seeds was positively correlated with the dry weight of seed lost during the first five days in the petri dish and at emergence ($r = 0.90^{**}$), dry weight of new growth (radicle and plumule) at the end of the fifth day in petri dish (0.55^{**}) and at emergence in the field ($r = 0.88^{**}$). Initial dry weight of seeds (and dry weight of seeds lost at emergence) was positively correlated with the dry weight of plumule ($r = 0.52^{**}$), dry weight of radicle (0.85^{**}) and the ratio of radicle dry weight to plumule dry weight ($r = 0.76^{**}$). Dry weight of seed lost during the first five days in the petri dish and in the pot and field at emergence was positively correlated with the dry weight of new growth ($r = 0.89^{**}$). Dry weight of new growth at emergence was positively correlated with the dry weight of seedling at 15 days in the field and at 30 days in the pots ($r = 0.48^{**}$). Therefore the absolute weight of seed reserves mobilized for new growth during germination and seedling size at 5, 15 and 30 days increases with increase in seed size. However, the association between seed size and seedling size at 15 and 30 days after emergence, although significant, is not a very strong one. It indicates that big seedlings at 15 and 30 days are produced from big seeds but not all big seeds produce big seedlings. This is because the photosynthetic area and efficiency after emergence also influences the rate of growth of seedlings after emergence. The evaluation procedure we are now using to identify seedling vigour is therefore based on the growth performance of genotypes during the 15-day period after emergence in the field compared to a check.

A brick chamber method was tested for its usefulness for studying root development by growing CSH-1 and 22E in three chambers which were dismantled at 45, 60 and 75 days. We found that the brick chamber method is capable of showing differences in root development and has a potential to enable us to evaluate more genotypes. For example, the average dry weight of roots per plant at all stages was greater in 22E than in CSH-1 (32 and 25 gm respectively at 75 days) - the average length of each main root at all stages was greater in 22E than in CSH-1 (35 and 27 cm respectively at 75 days); root/shoot ratio at all stages was greater in 22E than in CSH-1 (0.48 and 0.35 respectively at 75 days).

A field study on panicle development in CSH-1, 22E and their parents was made during GS2 and GS3. Although results have not been fully analyzed, it appears that CSH-1 does not deviate appreciably from its parents in its developmental time table and panicle characteristics whereas 22E deviates greatly from its parents.

PHYSIOLOGICAL SOURCE MATERIAL

Source material for various physiological attributes were identified for use in the breeding programme. These include: 25 genotypes with seedling vigour, 8 genotypes with above average nitrogen uptake and transfer efficiency to the grain, 20 genotypes with carbohydrate source and/or sink attributes, and drought resistant genotypes.

MICROBIOLOGY

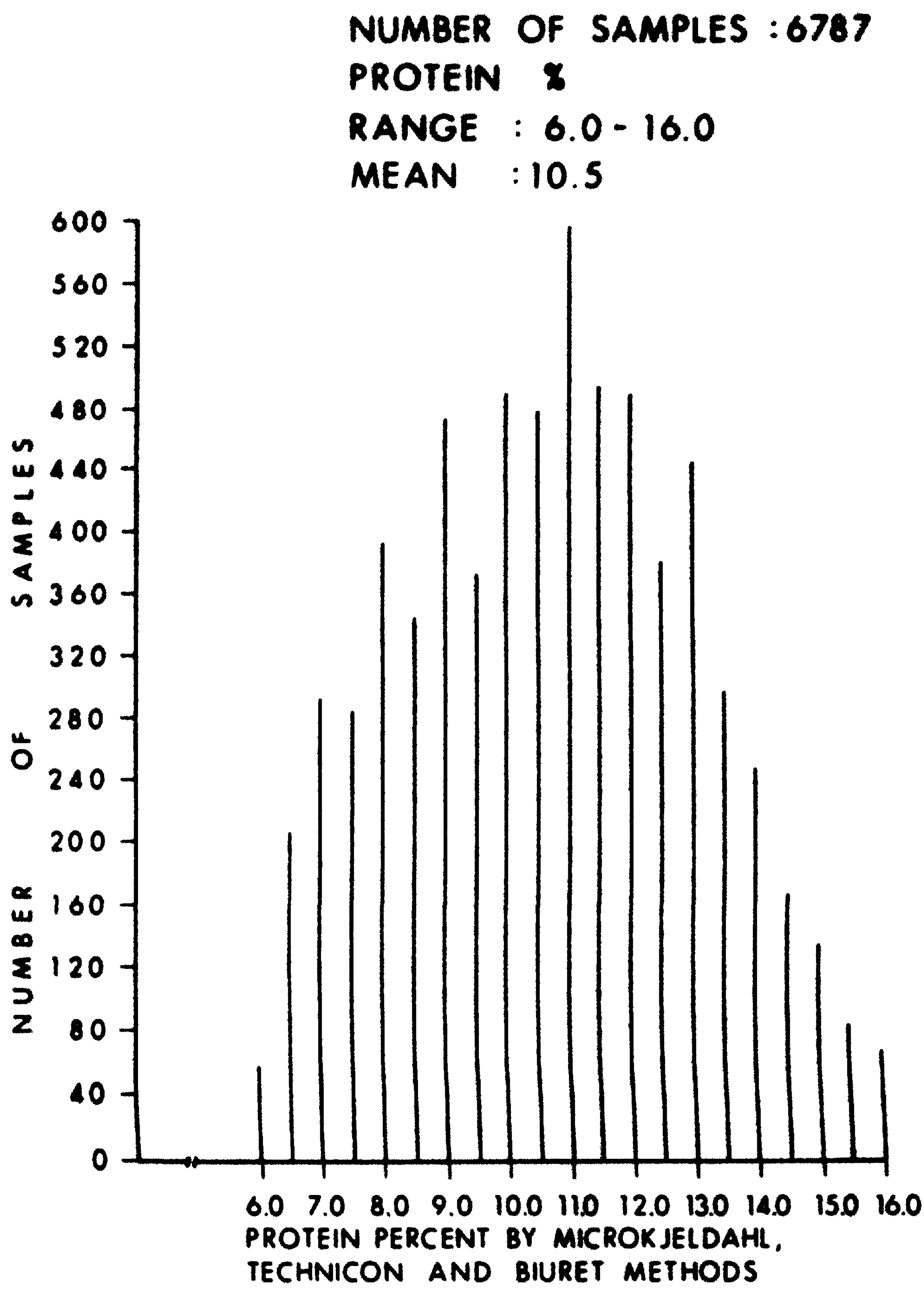
One hundred and fifteen sorghum lines, hybrids and related species which performed well under both low and high fertility conditions were grown under low fertility conditions (20 kg N, 9 kg P/ha fertiliser) during the rabi season 1975-76 and evaluated for their ability to stimulate the nitrogenase activity of rhizosphere bacteria. Washed root systems were assayed by acetylene reduction in 320 ml bottles after an overnight preincubation under c 1% O_2 in Argon or Nitrogen. Nitrogenase activity varied between lines up to forty fold with a maximum activity of 4.3 umol/plant/ha or 1.2 umol/g dry weight of root/h. In lines stimulating much activity some plants had little activity so that differences between replicate plants could be as much as eighteen fold. Variability in plant growth induced by shoot-fly attack may be partly responsible, as well as differences in oxygen tension around the roots during the assay. Much nitrogenase activity was associated with 10 entries which included the hybrids CSH-1 and CSH-5, and *Sorghum halepense*. Activity was greater after flowering than before and continued well into the grain filling stage for these irrigated plants. Most plants did not look nitrogen deficient. Our work will concentrate first on developing a suitable acetylene reduction assay system so that we can reliably identify lines which stimulate much nitrogen fixation.

BIOCHEMISTRY & NUTRITION

Routine screening was carried out on about 7000 sorghum samples for protein and lysine (basic amino-acids) during the year. Figure 3 gives the frequency distribution for present protein content.

The UDY instrument reading (UIR, representing present transmission) was taken for a constant protein level of 80 mg. for all samples, giving an estimate of total basic amino-acids. Figure 4 represents the frequency distribution for the UIR readings of the 7064 samples.

FIGURE : 3 SORGHUM 1975-76



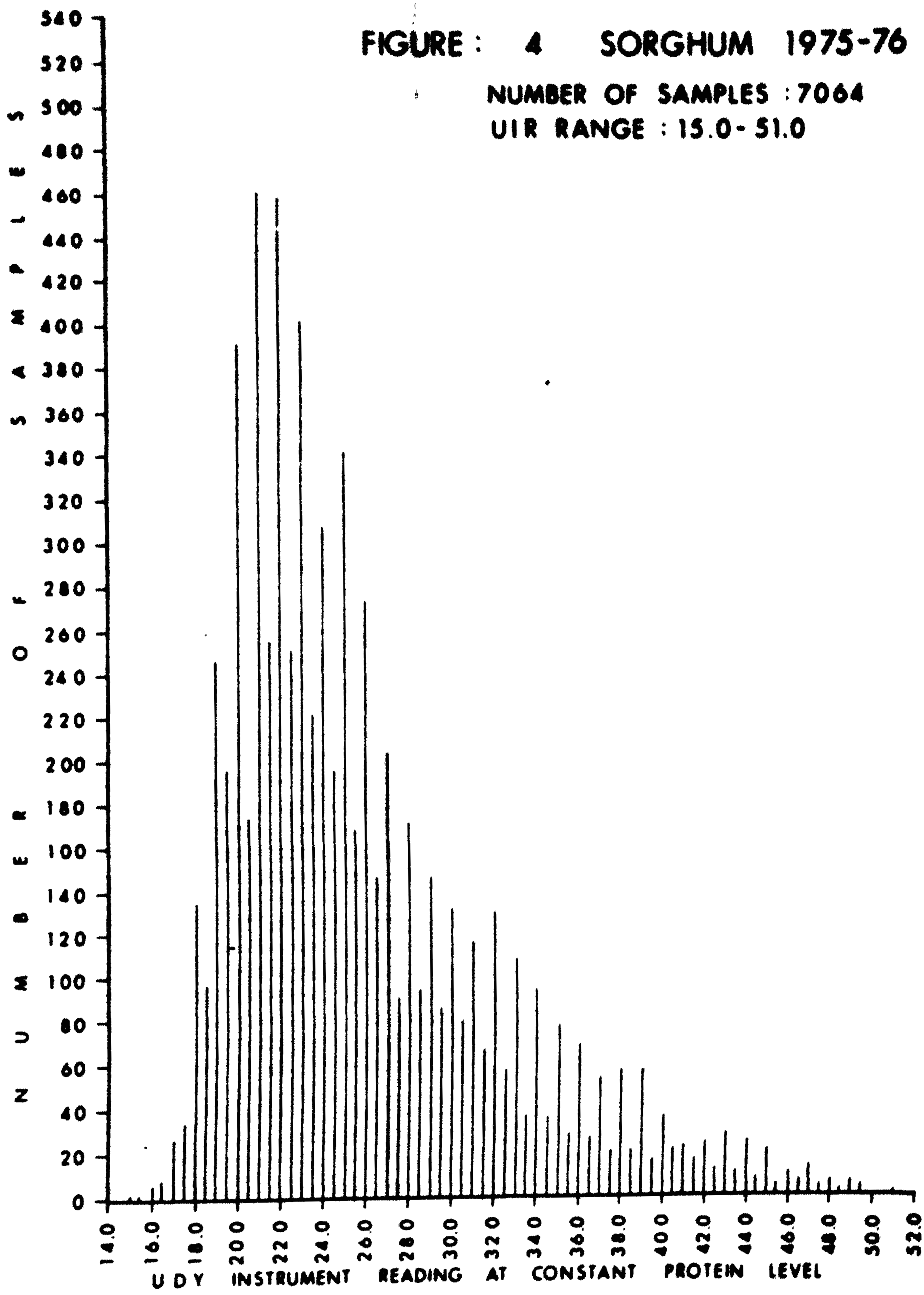


FIGURE : 4 SORGHUM 1975-76
NUMBER OF SAMPLES : 7064
UIR RANGE : 15.0 - 51.0
NUMBER OF SAMPLES
540
520
500
480
460
440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
32.0
34.0
36.0
38.0
40.0
42.0
44.0
46.0
48.0
50.0
52.0
UDY INSTRUMENT READING AT CONSTANT PROTEIN LEVEL

Table 22 gives the source and description of the samples that were analysed during 1975-76.

TABLE 22: SORGHUM: DESCRIPTION AND RESULTS OF SAMPLES ANALYSED DURING 1975-76

Date received	Lab No.	Source & Description	Protein % range	UIR Range
Mar. 75	4681-4718(38)	P721 Mutant and Degan Village Bulk	9.2-16.9	20.5-30.0
Apr. 75	4793-4892(100)	World collection (without sub-coat) - KEPR	8.0-15.9	19.0-30.0
May 75	4893-6803(1911)	Purdue University-Single and three way crosses	6.0-16.0	17.5-44.5
May 75	6805-9035(2231)	Purdue University-Single and three way crosses	6.0-16.0	15.5-51.0
Nov. 75	9037-10339 & 10689-11937(2649)	Material harvested from R6	5.6-17.9	15.0-45.0
Dec. 75	10442-10457(16)	K-black soil - 4 levels of N fertilizer	5.0-9.8	25.5-44.0
Dec. 75	10458-10688(231)	Group I - High DBC value Group II & III	6.4-17.4	17.5-30.0
Jan. 76	11938-12029(92)	Farmers samples - R75 - Khammam District	5.4-12.8	19.0-34.0

Initially, protein was estimated by the biuret method, but it was noted that this method was underrestimating, especially at low protein percentages. Therefore, samples which showed high UIR were analysed for their protein content by the microKjeldahl method, then a fresh UDY determination was made. Later, analysis for protein were carried out either by the microKjeldahl method or by the Technicon auto analyser method

Twenty three sorghum samples were analysed for starch and fibre by the Tropical Products Institute, London. Protein and hundred seed weight of the grains were determined in our laboratory. It was observed that the starch was significantly negatively correlated with protein (-0.68**) and fibre (-0.70**). Protein was positively correlated with fibre (0.77**). No significant correlation was obtained between the hundred grain weight and protein or starch or crude fibre.

FUTURE PROGRAMME

PLANT BREEDING

Testing of large numbers of lines derived from populations will be done at co-operating centres in India and Africa. We shall then create a series of Advanced Populations from these lines to match appropriate rainfall durations and special situations such as the rabi areas of India and the bird areas of Africa. These new populations will serve as sources of well adapted material for plant breeders in the appropriate ecological zone. Special attention will be given to improving the levels of shoot-fly resistance, grain mould resistance, and pest resistance in these populations, involving the development of "side-cars" and learning how to use them most effectively.

Similarly, the development of lines by pedigree breeding combining good agronomic characters with the best levels of pest, striga, and mould resistance will be continued, giving special attention to enhancing existing resistance levels through recombination of resistances from diverse sources.

The number of small, multilocation trials of elite lines in the SAT outside India will be increased as more and better material becomes available. Within India, the trials will be done on Patancheru only at high and low fertility levels, and the best material will then be submitted to AICSIP for consideration as entries in the AICSIP preliminary trials. It is not our intention to produce lines as ICRISAT lines, but rather to make them available to national programmes for local designation, multiplication, and release.

Evident grain quality improvement will receive increased attention, in co-operation with other institutes, and the problems of improving the grain lysine content will be studied further. The programme for grain-grass sorghums will be expanded, studying their usefulness at varied plant population levels, drought endurance, ratooning potential, pest and disease resistance levels, and performance under low night temperatures.

GERMPLASM

Work will continue on data collection for a first sorghum germplasm catalogue in co-operation with the Teximetric Laboratory, Colorado. As soon as the cold storage facilities become available and a germplasm scientist is appointed, the complete world collection will be obtained, and all observations computerized. Collecting work will be organised in conjunction with

IBPGR directed especially at geographical gaps in our present collection. Additional collecting will be done within India.

ENTOMOLOGY

Screening activity will intensify and progressively emphasis will switch from screening of established cultivars towards assessing material coming forward from the breeding programmes. In the Kharif of 1976, small areas of cultivars shown to have tolerance to shoot-fly will be grown in bulks and observations will be carried out on the biology of *A. soccata* and *C. partellus* in them. Six pest nurseries derived from the screening work will be sown in Africa and detailed observations carried out by co-operating scientists.

Studies on carry-over of both *Chilo* and *Atherigona* will continue. The fish meal baiting technique will be used to attempt to elucidate the role of aestivation as opposed to alternative host plant as a source of *Atherigona* carry-over and the pheromone of *Chilo* used extensively at the break of the monsoon to ascertain population levels and fluctuations.

More work on the biology of the pests will be initiated and it is hoped to make a start on storage studies in early 1977.

PATHOLOGY

Work on the identification of good disease and mould resistance sources will be intensified, and techniques for screening breeders' material against as many diseases as possible will be perfected. The International Sorghum Disease Resistance Testing Programme, already planned in conjunction with scientists in national and regional programmes in India, Africa and USA will be initiated. (see p. 50 of report). The aims of the programme are to identify sources of broad spectrum stable resistance to diseases, to distribute useful germplasm to interested workers, to provide information on the pathogenic variability within pathogen species at different locations, and to act as a communication link between sorghum breeders and sorghum pathologists in different regions.

PHYSIOLOGY

To understand the genotype x environment interaction, investigation needs to be extended to using breeding material at multi-location sites to study the physiological basis of narrow and wide adaptability.

The analysis of associations between carbohydrate source and sink attributes should enable us to define the best combination of attributes for a given maturity class to produce a given yield. Preliminary examination of the nitrogen content data of plant samples from plants with high and low tissue nitrate content, identified using a rapid chemical colour test, has shown that plants with high nitrate have 1-2% more protein. We hope to test this method on a larger number of genotypes in our search for genotypes with superior nitrogen physiology. We hope to expand the drought resistance work to evaluate promising lines from the field test for their response to osmotic stress during germination. We plan to use brick chambers to examine the nature of the root system of contrasting drought resistant genotypes identified in the field. The physiological source material which we have already identified will be used to develop physiological breeding populations.

MICROBIOLOGY

The programme will concentrate on the perfection of the assay technique for nitrogenase activity, and of the methodology for establishing differences between cultivars. More breeders' material and germplasm collection entries will then be screened, to identify the cultivars associated with the highest levels of activity, for use in the breeding programme.

BIOCHEMISTRY

The technology of screeing large numbers of plant breeders' samples for protein, basic amino-acid content, and lysine levels will be improved, and streamlined to handle larger sample numbers as expeditiously as possible.