RP /02083

Dr. L.D. Swindale

Progress Report
PRODUCTION AGRONOMY

REPORT OF WORK

1978-1979

PRODUCTION AGRONOMY

FARMING SYSTEMS RESEARCH PROGRAM

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics

ICRISAT Patancheru P.O.

Andhra Pradesh, India 502 324

NOTE TO THE READER

This is pre-publication informal report of work for June 1978-May 1979. This report is designed to stimulate thinking and comments from professional colleagues and is not to be considered as a formal publication bearing the endorsement of the Institute.

This is one of seven subprogram reports from the Farming Systems Research Program. The seven subprogram reports include the following:

- Agroclimatology
- Environmental Physics
- Soil Fertility & Chemistry
- Farm Power & Equipment
- Land & Water Management - Hydrology
- Cropping Systems
- Production Agronomy

Research Projects under Production Agronomy include weed management research, forage, fodder and fuel crops investigations and agronomy investigations on an operational-scale.

PRODUCTION AGRONOMY STAFF 1978-1979

Dr. B.A. Krantz	.....	Principal Agronomist & Program Leader (Retired since March 1979)
Dr S V.R Shetty	.....	Agronomist
Mr. S K. Sharma	.....	Sr. Research Technician
Mr. S.A. Ram	.....	Technical Assistant
Mr. L Mohan Reddy	.....	Technical Assistant
Mr. S.L.N. Reddy	.....	Technical Assistant
Mr. M.M. Sharma	.....	Technical Assistant
Mr. Harbans Raj	.....	Technical Assistant
Mr. Peter John Bob	.....	Field Assistant
Mr. K.L. Kanta Rao	.....	Field Assistant
Mr. V Mohan Reddy	.....	Field Assistant
Mr. K. Ashok Reddy	.....	Field Assistant
Mrs. S. Nakra	.....	Administrative Assistant
Mr K.S T.S. Vara Prasad	.....	Clerk/Typist

Dr. A N. Rao	.....	Post-Doctoral Research Fellow (Since August 1978)
Mr. E.L.P. Davies	.....	Post-Graduate Trainee (Till Jan. 1979).

LIST OF CONTENTS

A WEED MANAGEMENT RESEARCH

During the year, weed management research was intensified by including further studies on the manipulation of various factors affecting crop-weed associations. Field trials were conducted to examine the degree of weed suppression by including additional crops, manipulating crop density, fertility level, row arrangement, and time of weed removal. Evaluation of various weed control measures including herbicides for double cropping in deep Vertisols received greater attention. Emphasis was also given on determining the weed competitive ability of different cultivars of ICRISAT-5 crops.

In addition to agronomic studies in the field, laboratory studies were also initiated to understand the eco-physiology of weeds as affected by alternate crop and soil management systems. Studies to determine the response of a few weeds to different levels of shading and the trends in weed growth in different seed bed systems were initiated to quantify the effect of physical and cultural factors affecting crop-weed associations.

"On-farm" weed research investigations were intensified to build up further information and understanding on the farmers' present weeding systems and the performance of improved weed control systems under the farmers' existing farming systems and socio-economic situations.

A survey of the weed flora of ICRISAT was also conducted and a list of major weeds at ICRISAT Center is given in the Appendix I.

1. Intercropping:

Previous results indicate that the weed growth in the intercrop system was influenced by different factors like crop species, crop type, row arrangements, time of weed removal etc. The manipulation of these factors showed high promise for minimising weed infestation. Field trials were conducted both in Alfisols and Vertisols to further examine the increased weed suppression in different intercropping systems. Studies include inclusion of additional crops (smother cropping), manipulation of row arrangements, evaluation of herbicides, and weed removal at different times of crop growth to obtain better management of weeds.

1.1 Smother Cropping:

Two field trials were conducted (one each in Vertisols and Alfisols) to further investigate the influence of "smother cropping" of cowpea and mungbean on the intensity and composition of weed infestation and to determine whether the addition of these quick and short duration legumes could replace hand weedings without affecting total crop productivity. The treatments included varying levels of hand weedings (two, one or no hand weedings) in sole cropping of sorghum and pigeonpea and sorghum/pigeonpea intercrop systems with and without inclusion of "smother" crops. The details of the treatments and the results are presented in Tables 1 and 2. The row spacing followed in sole cropping was 45 cm, but in intercrop system it was adjusted to 60 cm to explore the possibility of minimising competition among crops in 3 crop system.

The results in Tables 1 and 2 indicate that the inclusion of additional crops cowpea and mung minimised weed competition and virtually replaced one hand weeding without significantly affecting the sorghum yields especially in Vertisols. As in last year cowpea performed very well in Alfisols. The competition offered by cowpea, however, seemed to be severe when compared to mungbean.

There were no significant differences between sorghum yields in sole and smother cropping systems in Vertisols. Therefore, the advantage of 'smother' crop is the additional yields of the smother crop and the elimination of one hand weeding. Though there were significant differences in pigeonpea yields, the total production from the smother cropping system was higher than pigeonpea sole. However, in sorghum/pigeonpea intercrop both the pigeonpea and sorghum yields were affected when an additional crop was included. In spite of adopting 60 cm spacings the decline in main crop yields was noticed and there does not seem to be any additional gains by replacing hand weedings and including additional gains by replacing hand weedings and including additional 'smother'

Table 1: The effect of smother cropping on the weed growth 1978-79.

Treatments	ALFISOLS				VERTISOLS			
	Sorg. yield	P.pea yield	Smother crop yield	Weed yield at sorg. harvest	Sorg. yield	P.pea yield	Smother crop yield	Weed yield at sorg. harvest
	kg/ha	kg/ha	kg/ha	g/m^2	kg/ha	kg/ha	kg/ha	g/m^2
Sorghum + 2 H.W.*	4046	-	-	34.2	4560	-	-	5.2
Pigeonpea + 2 H.W.	-	1216	-	64.5	-	1237	-	24.2
Sorghum + 2 H.W. Pigeonpea	3290	600	-	29.2	4354	1122	-	2.8
Sorghum + 1 H.W. Cowpea	2830	-	838	42.0	4075	-	165	5.5
Pigeonpea + 1 H.W. Cowpea	-	831	812	148.2	-	912	546	58.7
Sorghum + 1 H.W. Mungbean	3415	-	355	77.5	4466	-	134	20.5
Pigeonpea + 1 H.W. Mungbean	-	822	410	197.1	-	908	421	63.7
Sorghum + Pigeonpea + 1 H.W. Mungbean/Cowpea	2703	577	485	78.8	3758	826	204	41.8
Sorghum + Pigeonpea + No H.W. + Mungbean/C.pea	1567	369	422	271.1	2998	509	170	149.3
C.D. at 5%	744.0	170.5	-	21.3	462.2	237.3	-	7.9

*H.W. = Hand weeding.

Table 2: Net production in terms of monetary value of various Cropping Systems in 1978-79.

S. No.	System	Total production Rs/ha		Net production Rs/ha**	
		Alfisols	Vertisols	Alfisols	Vertisols
	Sorghum System				
1.	2 Hand weedings	2792	3146	2552	2906
2.	S + CP (1 hand weeding)	4467	3307	4287	3127
3.	S + M (1 " ")	3421	3483	3269	3331
	Pigeonpea System				
4.	2 Hand weedings	2736	2783	2496	2543
5.	PP + CP (1 hand weeding)	4306	3690	4126	3538
6.	PP + M (1 " ")	3080	3306	2928	3154
	Sorghum + Pigeonpea System				
7.	2 Hand weedings	3620	5529	3380	5289
8.	S + PP + CP/M (1 hand weeding)	4613	5064	4438	4912
9.	S + PP + CP/M (No hand weeding)	3178	3724	3118	3692

*Monetary value considered:

Sorghum Rs. 69/q
Pigeonpea Rs. 225/q
Cowpea Rs. 300/q
Mungbean Rs. 300/q

**Net production

= Total production - [Hand weeding cost + Smother crop seed cost]

Mungbean Rs. 32/ha
1 Hand weeding Rs. 120/ha.

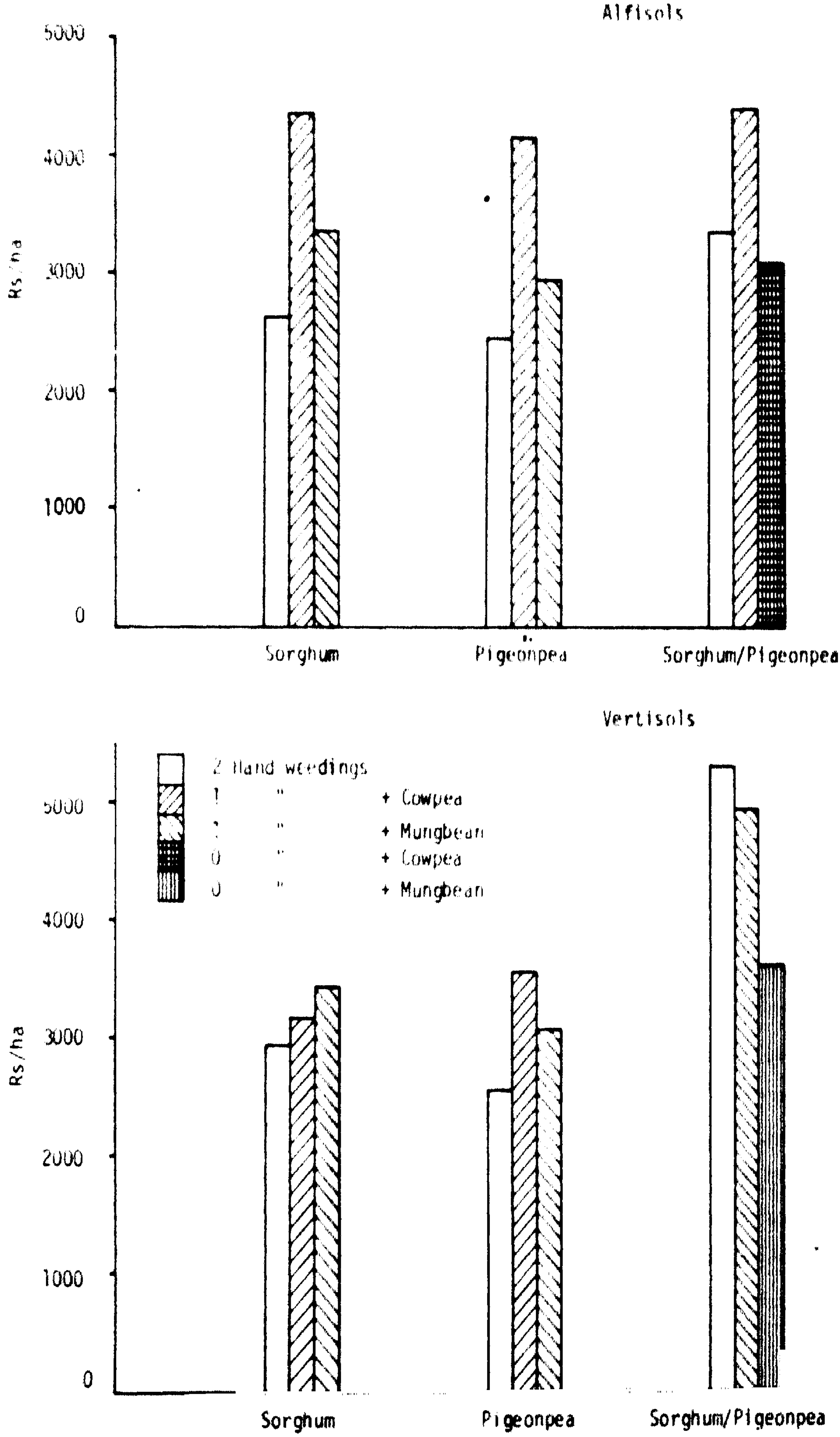

Fig. 1. NET MONETARY VALUE OF VARIOUS CROPPING SYSTEMS UNDER DIFFERENT WEED MANAGEMENT SYSTEMS, 1978-79.

crops. The cost of hand weedings and smother crops seeds were taken into consideration for evaluating the performance of different systems in the forms of net monetary value. It can be seen from table 2 and Fig. 1, that the net returns from sorghum + cowpea and sorghum + mung bean were considerably higher than the sorghum system alone. The advantage was more pronounced in Alfisols. In the pigeonpea systems the net returns from the pigeonpea + cowpea/mungbean were substantially superior to sole pigeonpea system on both the soils. In the sorghum/pigeonpea system, however, the system with 2 hand weedings was superior than 3 crop system with one or no hand weedings (Vertisols). But, in general, the 3 crop system with one or no hand weeding system resulted equal or higher net returns than sole crop of sorghum with two hand weedings. The same trends of results were also observed from the 1977-78 trials.

The weed dry matter weights (Table 3) indicate the weed competitive ability of different cropping systems (Figs. 2a to d). The inclusion of additional crops - cowpea and mungbean resulted in less weed growth in all the cropping systems. The weed suppression due to these additional crops was about the same as obtained with two hand weedings. After the harvest of 'smother' crops a new flush of weeds again started emerging, resulting in higher weed growth. However, these late season weeds were not competitive with the main crop (sorghum) as the crop was already well established. Among the 'smother' crops, mungbean being a quick grower was more efficient in suppressing weed growth initially, but later in the season cowpea performed better mainly because of its good canopy structure. There was a distinct difference in weed growth after the 'smother' crop harvest. While there was a marked increase in total weed dry matter after mung harvest, the weed dry matter weights did not differ much in cowpea plots before and after cowpea harvest. The same observation was noticed during previous years when the residual effect of cowpea seemed to have a detrimental effect on further weed seed germination later in the season.

Table 3: Biomass of weeds (g/m^2) in smother cropping system (Alfisols and Vertisols) at different stages

	Before I H.W.		At smother crop harvest		At sorghum harvest		At pigeonpea harvest	
	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols
Sorghum - 2 H.W.	15.6	29	1.8	22.02	5.19	34.26	32.88	73.8
Pigeonpea - 2 H.W.	13.6	30.6	3.7	28.86	24.17	64.5	96	153.8
Sorghum + Pigeonpea - 2 H.W.	16.6	14	1.9	8.1	2.76	29.24	64	56.48
Sorghum + Cowpea - I H.W.	7	8.3	1.14	4.92	5.48	22	60.36	99.6
Pigeonpea + Cowpea - I H.W.	15.7	13	11.62	17.7	3.8	48.24	89	108.24
Pigeonpea + Mungbean	14.3	15.8	9.06	20.4	33	57.5	99.12	128.7
Sorghum + Mungbean - I H.W.	5	13.5	2.28	11.8	20.52	30.1	83.86	134.5
Sorghum + Pigeonpea + Mungbean - I H.W.	11.3	17.3	5.08	24	31.79	51.7	94.53	141.7
Sorghum + Pigeonpea + Mungbean - No. H.W.	17.3	24.8	77.82	216.3	149.33	271.08	188.76	377.4
C.D. at 5%	-	4.55	6.62	16.64	14.32	17.73	11.24	16.39

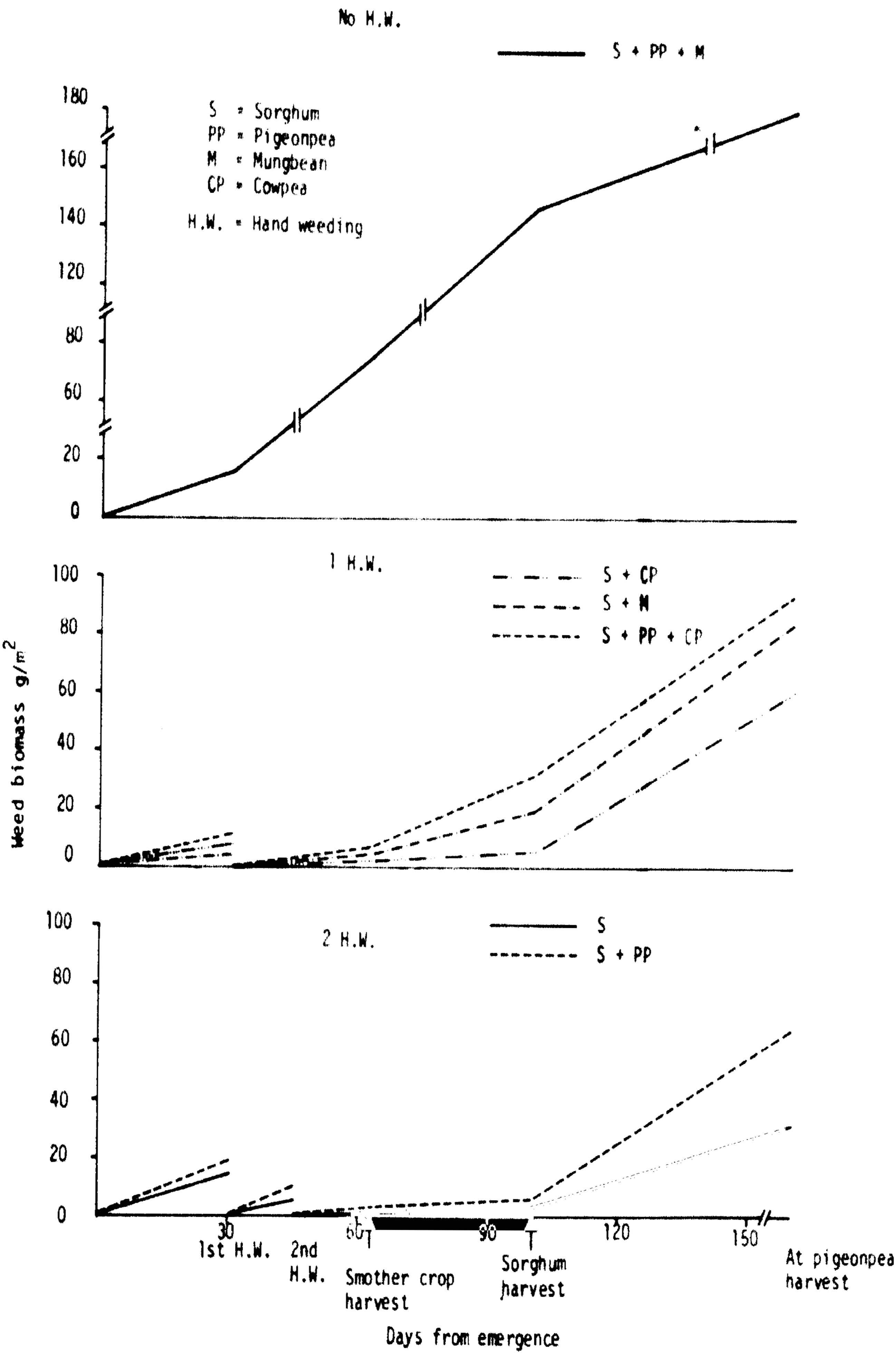

Fig. 2a. BIOMASS OF WEEDS AT DIFFERENT STAGES OF CROP GROWTH AS AFFECTED BY DIFFERENT SORGHUM BASED SMOTHER CROPPING SYSTEMS ON VERTISOLS, 1978.

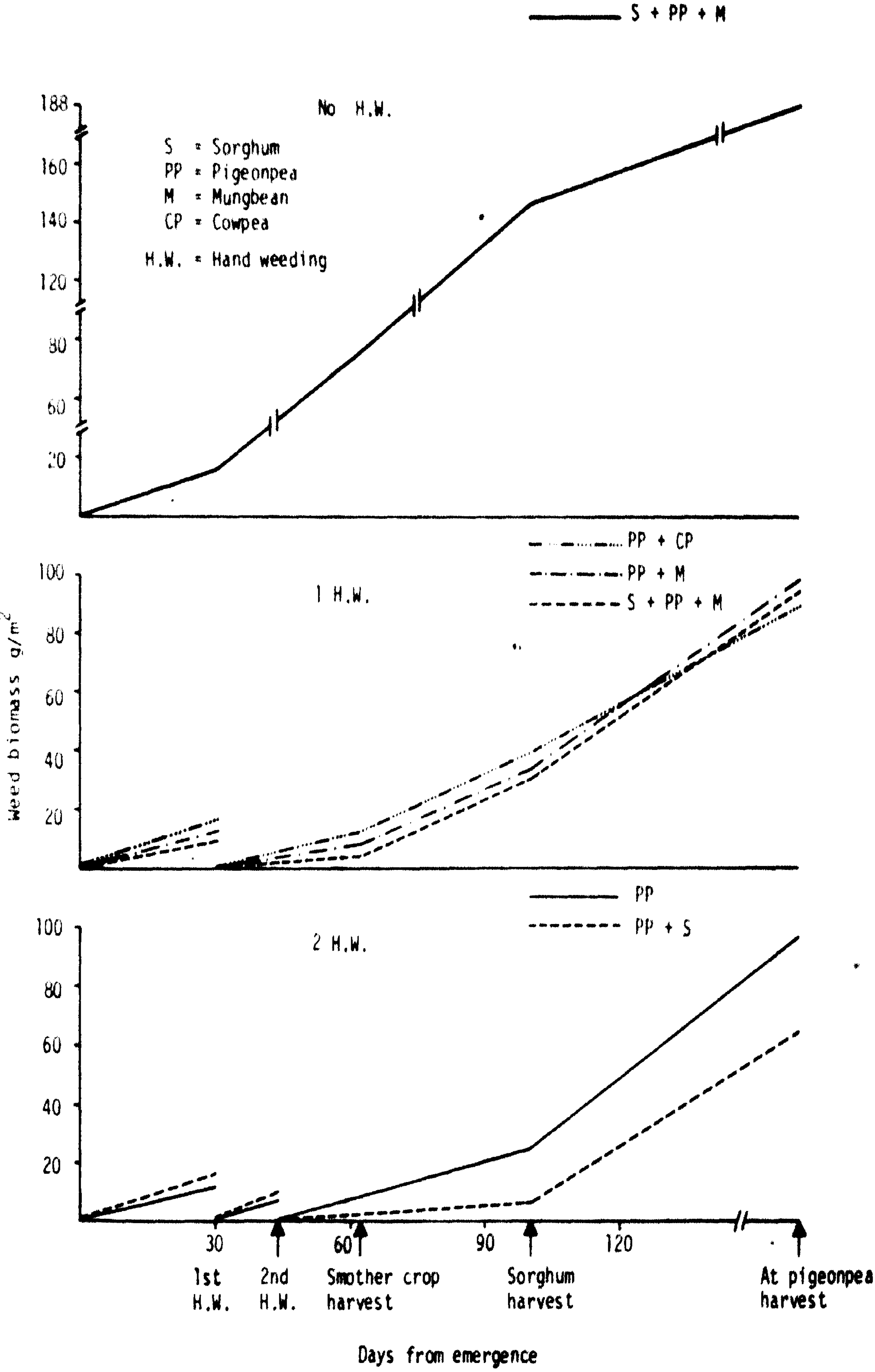

Fig. 2b. BIOMASS OF WEEDS AT DIFFERENT STAGES OF CROP GROWTH AS AFFECTED BY DIFFERENT PIGEONPEA BASED SMOTHER CROPPING SYSTEMS ON VERTISOLS, 1978.

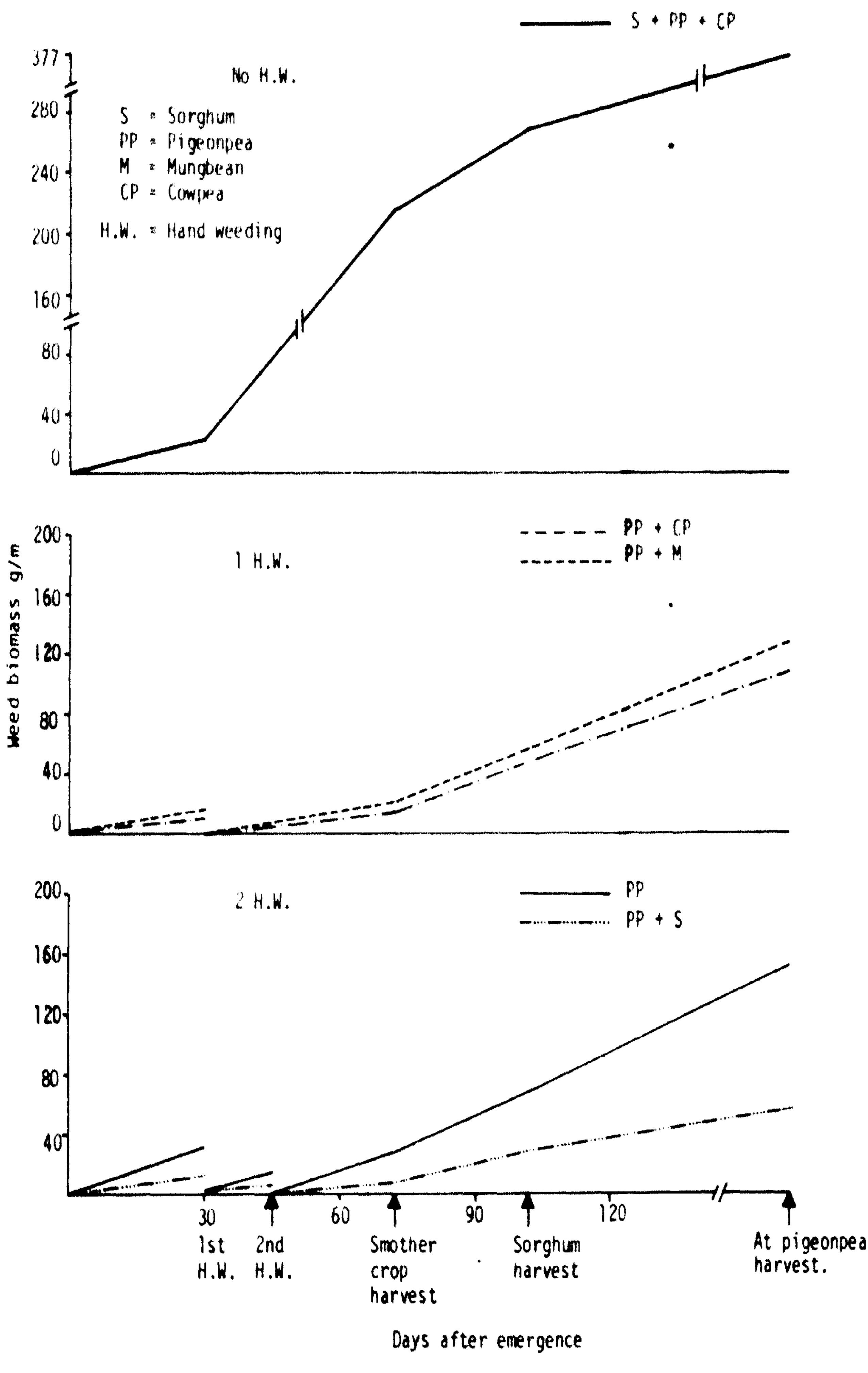

Fig. 2c. BIOMASS OF WEEDS AT DIFFERENT STAGES OF CROP GROWTH AS AFFECTED BY DIFFERENT PIGEONPEA BASED SMOTHER CROPPING SYSTEMS ON ALFISOLS, 1978.

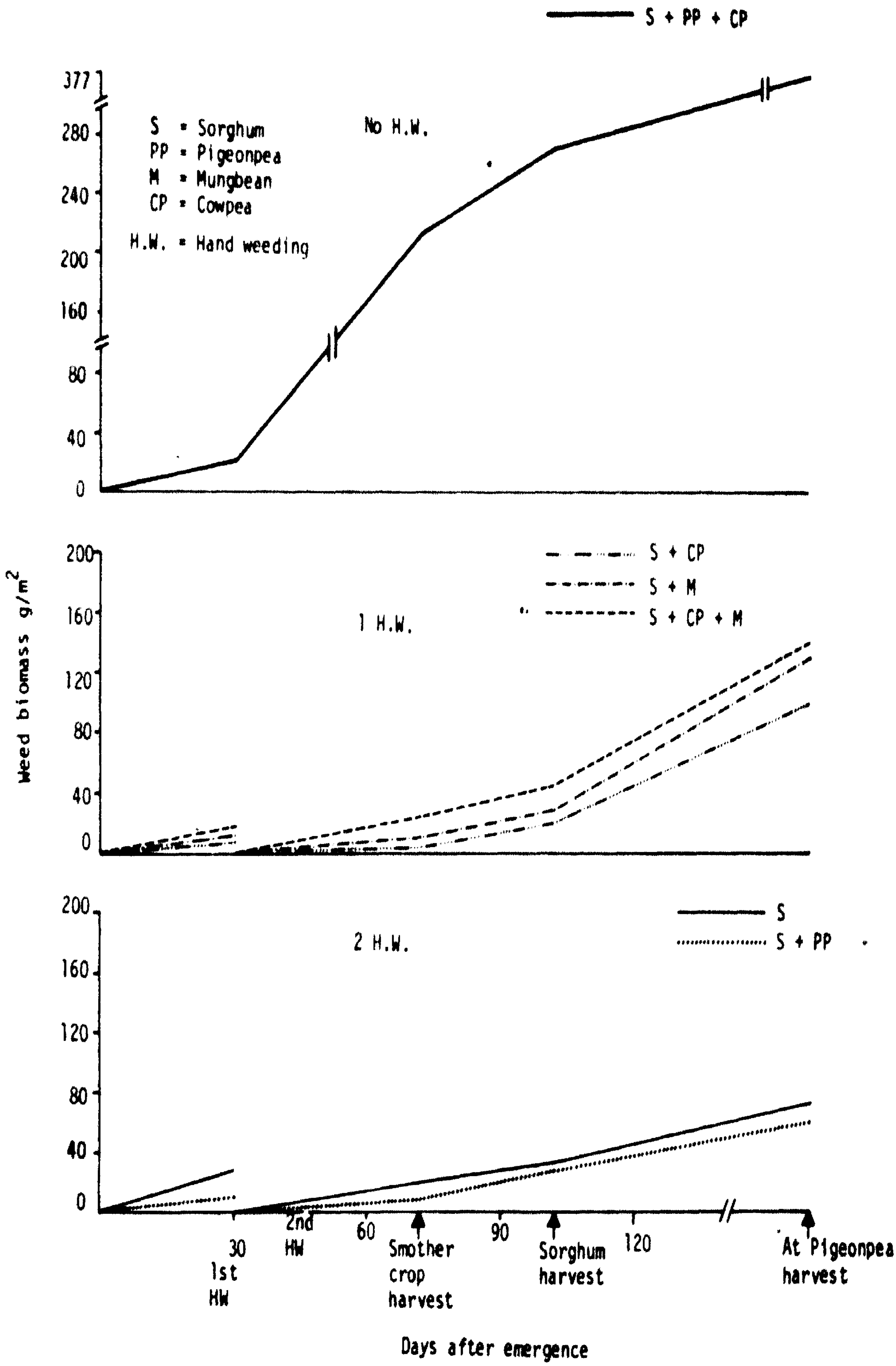

Fig. 2d. BIOMASS OF WEEDS AT DIFFERENT STAGES OF CROP GROWTH AS AFFECTED BY DIFFERENT SORGHUM BASED SMOTHER CROPPING SYSTEMS ON ALFISOLS, 1978.

1.2 Row Arrangement Effect:

To examine the weed competitive ability of pearl millet/groundnut intercrop in different row proportions a trial was conducted on Alfisols during monsoon 1978. Treatments included different row proportions of pearl millet and groundnut (1:1 to 1:6) in the intercrop situations to observe the trends in weed infestation as affected by different row arrangements of component crops. One initial hand weeding (at 3 weeks after planting) was given uniformly to all the treatments to keep the weeds from the dominating the crop. Frequent phyto-sociological observations on weeds were recorded to detect and compare variation and change in weed community as affected by the above modified environments. Density, relative density and biomass were used as a measure of detecting the trends in weed infestation as affected by various treatments.

The data shown in Table 4 and Fig. 3 indicate that when compared with respective sole croppings, groundnut suffered more because of competition by both pearl millet and weeds. As the groundnut rows were increased there was an increase in groundnut yields, whereas there was no significant change in pearl millet yields. This is due to the compensatory ability of the dominant pearl millet in the system. The row arrangement of 1:3 looked optimum as far as total advantage of the pearl millet/groundnut systems was concerned. Further increase in groundnut rows did not help in increasing groundnut yields. The LER data indicate that a maximum of 15 percent advantage was obtained with one pearl millet and three groundnut row arrangement.

The weed dry matter weights taken during pearl millet harvest showed the least weed growth in pearl millet sole system. The groundnut sole and 1 pearl millet to 6 groundnut system showed the highest weed dry matter values The seriousness of weed growth in groundnut and groundnut predominant system was evident not only in the quantity of weed growth but also in the composition of the weed flora. The relative composition of weed flora in different treatments indicates that the dominant weeds in pearl millet/groundnut intercrop system were *Digitaria*, *Celosia* and *Cyperus*. In pearl millet sole, the

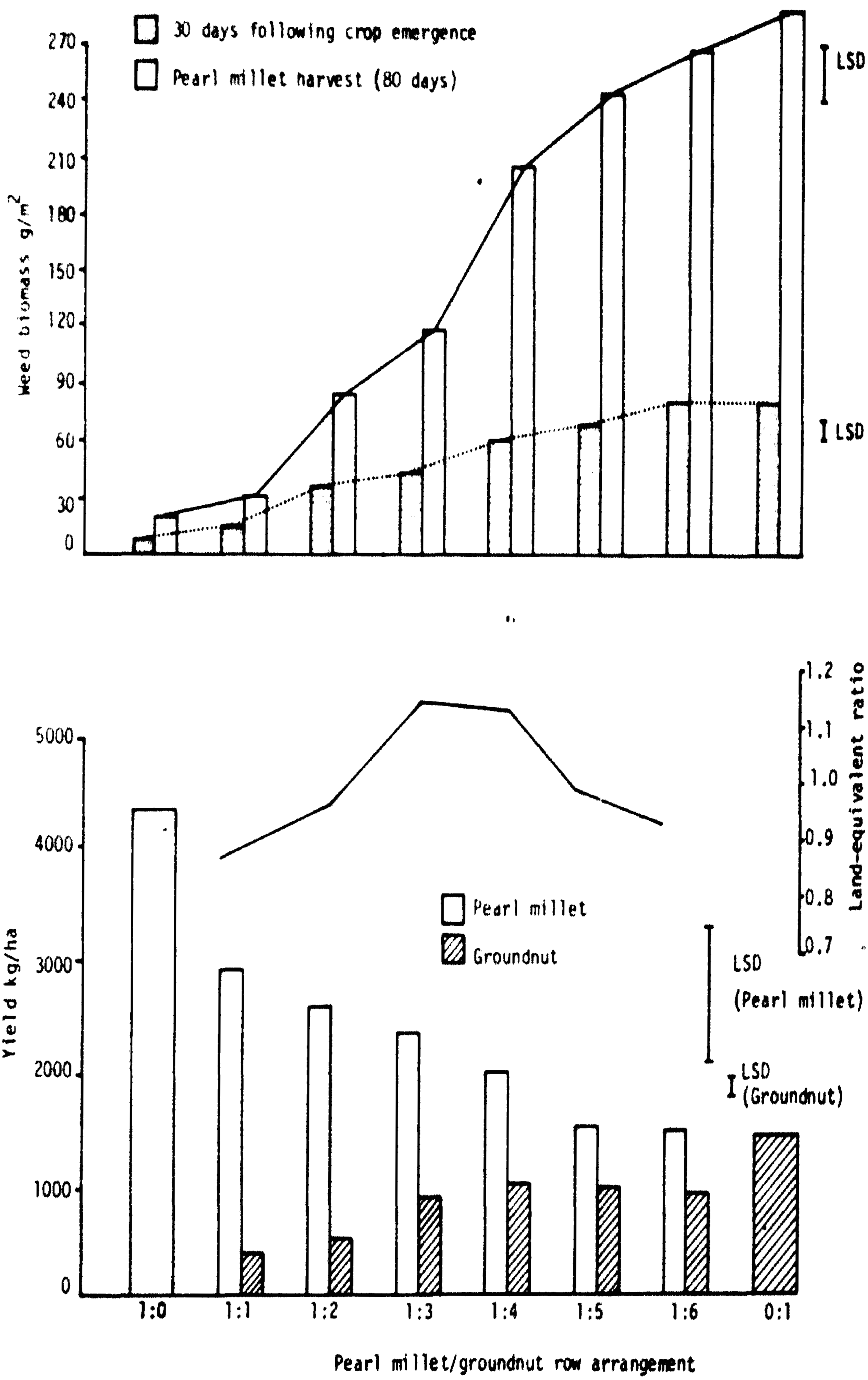

Fig. 3. EFFECT OF ROW ARRANGEMENT IN A PEARL MILLET/GROUNDNUT INTERCROP ON CROP ON WEED YIELDS ON ALFISOLS AT ICRISAT CENTER, 1978.

Table 4: Intercropping effect of pearl millet with groundnuts on crop and weed growth on Alfisols, 1978.

Treatments	Pearl millet yield kg/ha	Groundnut yield kg/ha	Weed dry matter at millet harvest g/m^2
Pearl millet sole	4298	-	19.3
Groundnut sole	-	1299	286.0
PM : GN 1:1	2490	388	31.7
PM : GN 1:2	2596	480	86.6
PM : GN 1:3	2303	810	116.7
PM : GN 1:4	1878	932	206.3
PM : GN 1:5	1464	748	243.6
PM : GN 1:6	1579	1107	266.7
C.D. at 5%	1163	680	26.9

weed flora comprised of a mixture of many weeds including *Digitaria*, *Cyperus*, *Celosia*, *Tridax*, *Phyllanthus*, *Eragrostis*, *Brachiaria*, while in groundnut sole the predominant weeds were only *Celosia*, *Digitaria* and *Cyperus*. As more rows of groundnuts were introduced in place of pearl millet rows the relative proportion of *Digitaria* increased to a certain extent and then remained constant, while that of *Cyperus* went on decreasing. But the more striking observation was the build up of more competitive and tall growing *Celosia* in the groundnut predominant systems. There appeared to be a shift in weed flora towards this particular weed as the groundnut rows were increased (Fig. 4).

The data on relative density of different reatments follows the same trend as that of weed dry matter weights except in the case of *Cyperus*. There was not much change in the density of *Cyperus* as the groundnut rows were increased but the dry matter weights decreased as indicated earlier. This can be attributed to the shade sensitivity of *Cyperus*. As the groundnut rows were increased the crop canopy provided

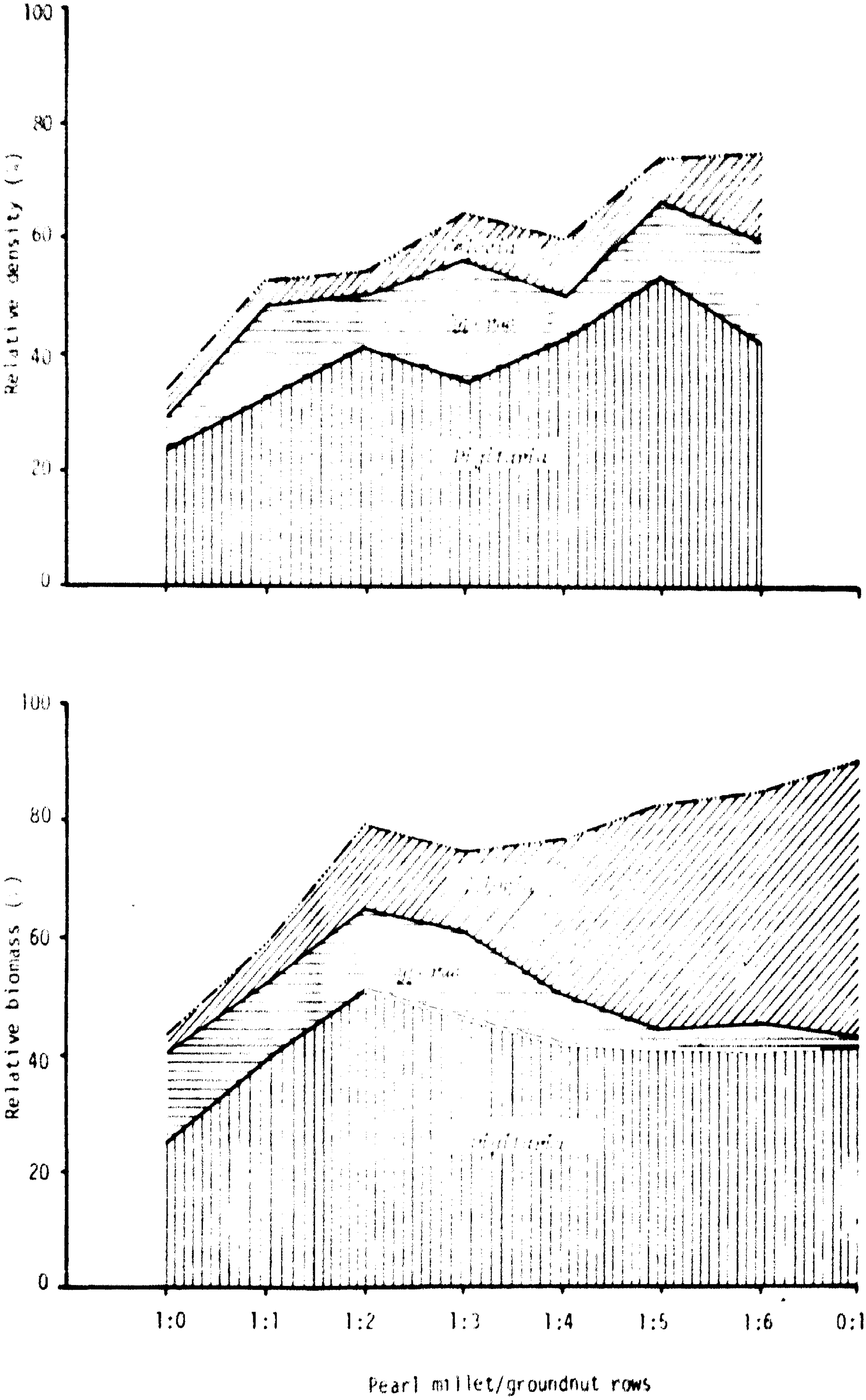

Fig. 4. PERCENTAGE CONTRIBUTION OF CELOSIA, CYPERUS, DIGITARIA AND OTHER WEED SPECIES TO THE TOTAL BIOMASS AND DENSITY OF WEEDS AT THE TIME OF PEARL MILLET HARVEST ON ALFISOLS AT ICRISAT CENTER, 1973.

a higher level of shading to *Cyperus*. As the groundnut rows were increased the crop canopy provided a higher level of shading to *Cyperus* resulting in poor growth to *Cyperus*. However, *Digitaria* and *Celosia* which are tall statured and usually grow above the groundnut canopy did not suffer and hence the greater dry weights.

The data on number of weeds in the crop row (Fig. 5) further indicate that as the intercrop system contains more groundnut the number of weeds in the crop rows tend to increase. Like wise, as the groundnut rows were replaced by pearl millet rows the number of weeds in the groundnut rows tend to decrease. Among the individual weeds *Celosia* was found to be more associated with groundnut rows where as it was found in negligible numbers in and around pearl millet rows

1.3 Time of Weed Removal:

To determine the effect of different times of weed removal on the intensity of weed growth during the remaining period of the crop season and on the crop yields of sorghum/pigeonpea intercrop a trial was conducted in the Vertisols during monsoon season of 1979. Hand weeding treatments were given at different intervals during the crop growth. The trials was also intended to identify the composition of the weed flora reemerging after weeding operations at different times of crop growth. The detailed treatments and the results are presented in Table 5 and Fig.

As seen in Fig. 6 the optimum sorghum yields were obtained when the one hand weeding was given at 5 weeks after planting. Hand weeding given earlier than 4 weeks reduced yields because of increased weed competition for a longer period while weeding later than four weeks resulted in prolonged weed competition earlier in the season. However, pigeonpea yields did not get affected at all. Therefore the weeding is more critical in early maturing cereal. In the two hand weeding system weedings given at 3 and 5 weeks after planting performed better than the weedings given at 4 and 8 weeks.

As the main objective of the trial was to observe re-growing weed flora (the weeds growing after the hand weedings), observations on individual weeds were taken during crop harvest. It can be seen from Fig. 7 that the total biomass of weeds in weedy check treatment was almost the same as in 1 hand weeding treatments. The weed growth in 2, 3, and 4 week hand weeding treatments were similar to that in weedy check treatment. Again, the relative composition of different weeds does not differ much in the 1 hand weeding and no hand weeding treatments. The major weeds in all the treatments were *Brachiaria eruciformis*, *Dinebra retroflexa*, *Euphorbia sp.* *Cyperus rotundus*, *Eragrostis diarrhena* and *Dactyloctenium aegyptium*. *Brachiaria* and *Dinebra* contributed more to the total biomass in all hand weeding and no hand weeding treatments. The weed dry matter and composition data indicate that though the timing of weeding has significant effects on crop yields the total weed growth at the end of the crop season does not differ much between the treatments.

Table 5: Effect of time of weed removal on weed re-emergence in sorghum/pigeonpea intercrop in Vertisols, 1978.

Treatments	Sorghum yield kg/ha	P.pea yield kg/ha	Weed drymatter gms/0.5^{2}M	Weed counts
1. Hand weeding after 2 weeks	2145	752	1335	436
2. " " 3 "	2347	755	979	268
3. " " 4 "	3442	1058	657	129
4. " " 6 "	3170	913	1089	274
5. " " 8 "	2485	822	1187	301
6. " " 3 + 5 " (2 hand weedings)	3717	1103	494	156
7. Hand weeding after 3+5+8 weeks (3 hand weedings)	4535	1109	276	69
8. 1 H.W. (4 weeks) + 1 H.W. immediately after sorghum harvest	3375	916	820	204
9. Weedy check	2035	622	1689	358
C.D. at 5%	689	277	140	142

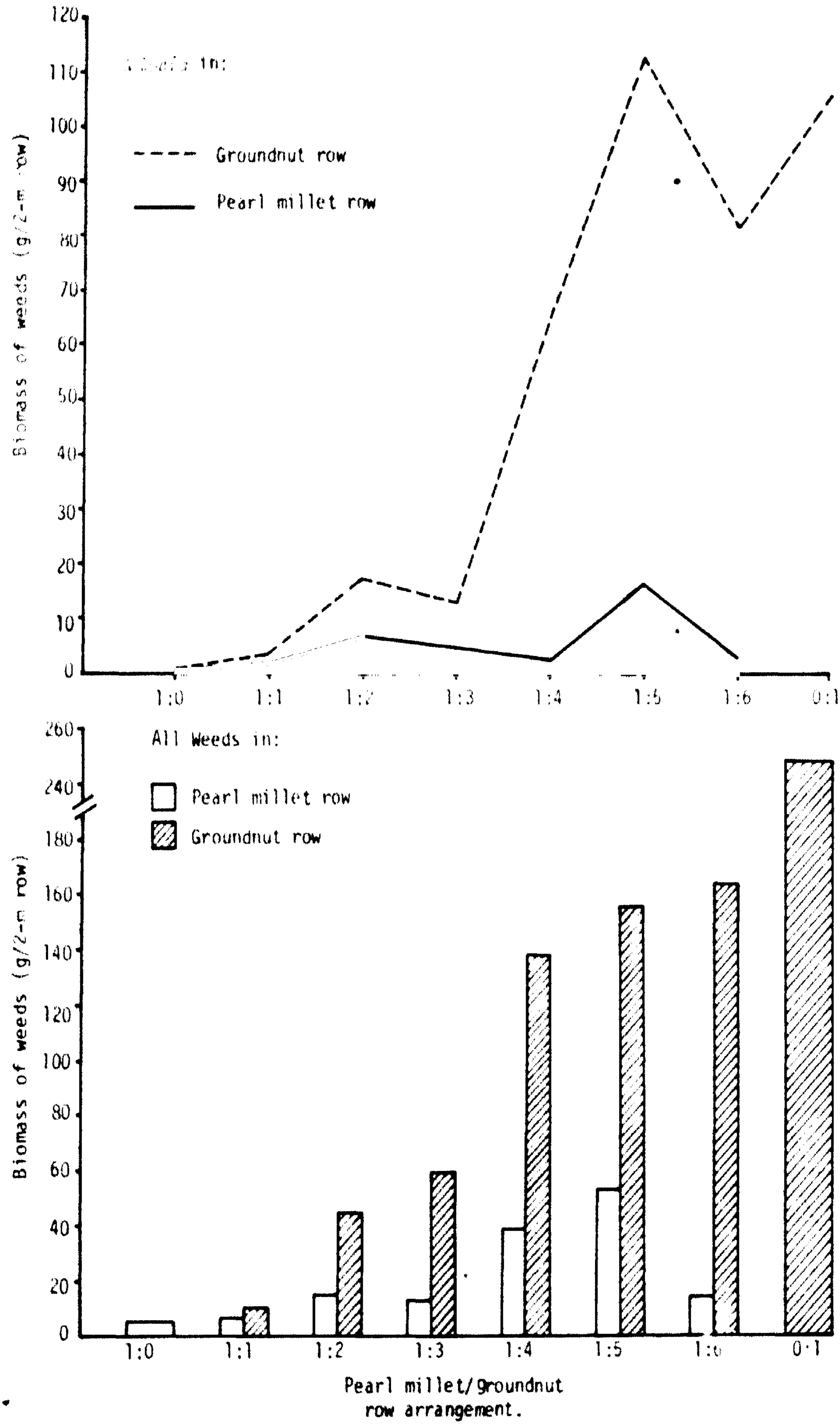

Fig. 5. EFFECT OF ROW ARRANGEMENT IN PEARL MILLET/GROUNDNUT INTERCROPS ON WEED GROWTH IN THE CROP ROWS ON ALFISOLS AT ICRISAT CENTER, 1978.

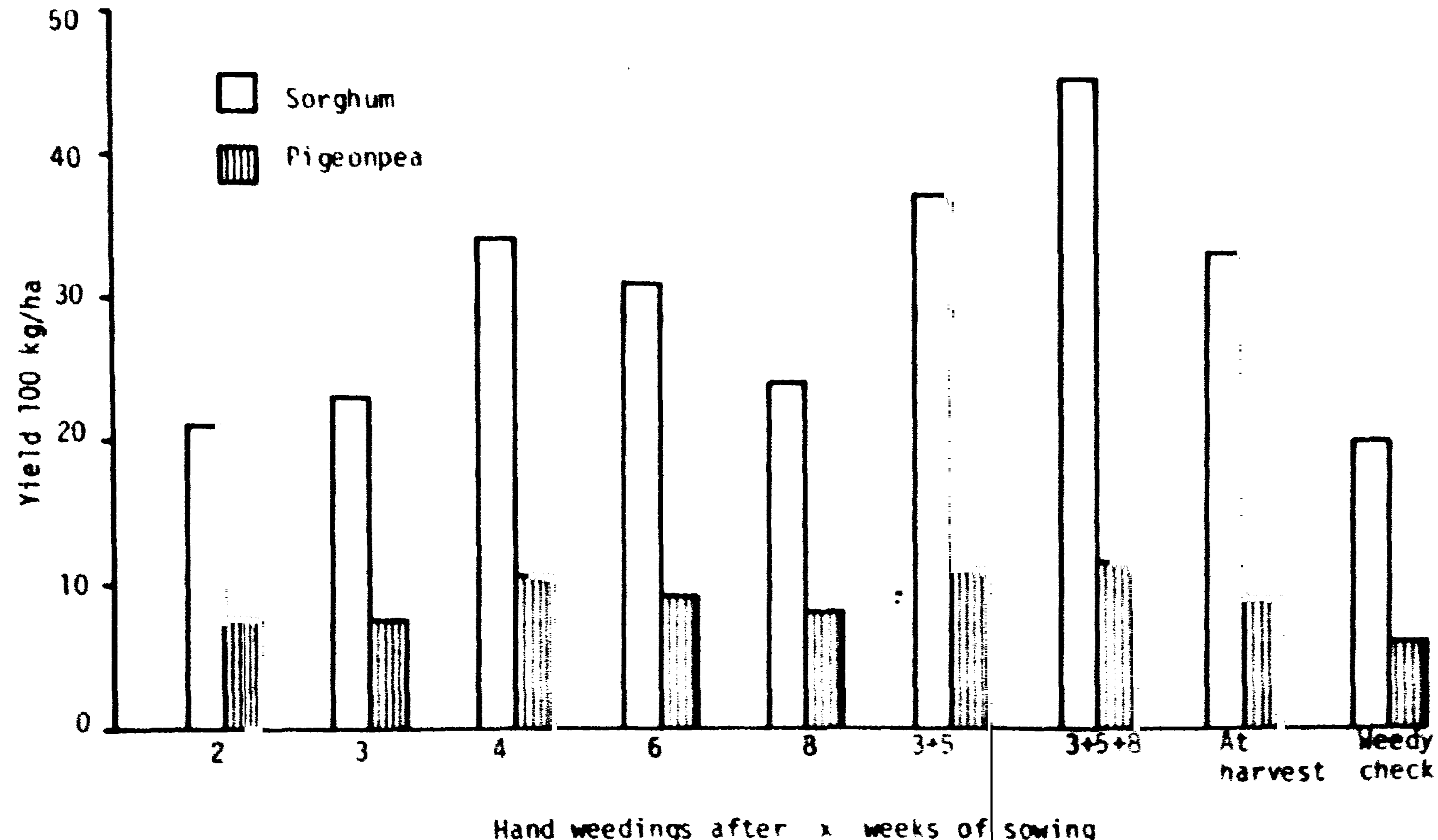

Fig. 6. EFFECT OF DIFFERENT TIMES OF WEED REMOVAL ON SORGHUM/PIGEONPEA YIELDS ON VERTISOLS, 1978.

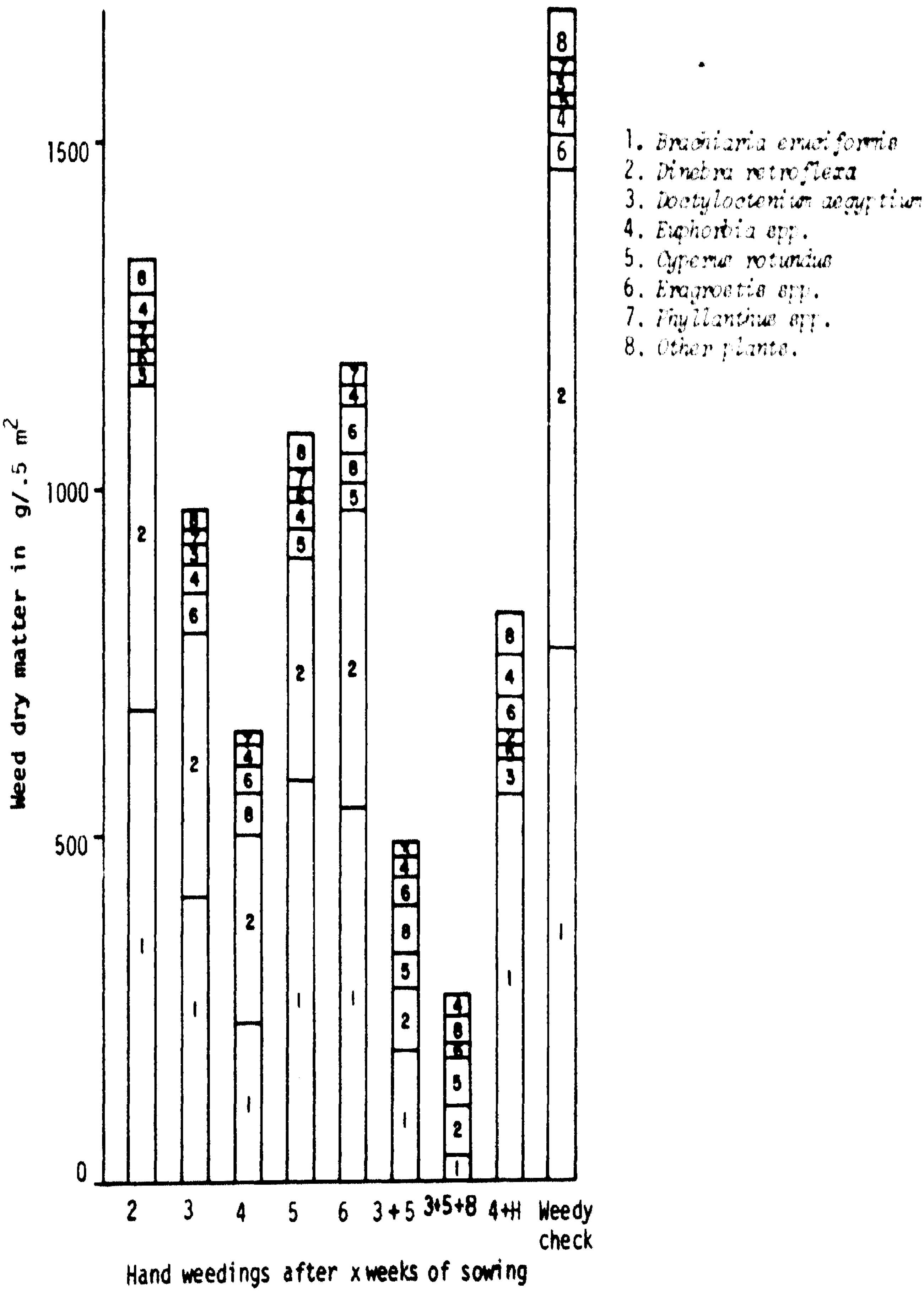

Fig. 7. EFFECT OF DIFFERENT TIMES OF WEED REMOVAL ON THE GROWTH OF DIFFERENT WEEDS ON VERTISOLS AT ICRISAT CENTER, 1978.

1.4 Herbicides:

During the past few seasons it was possible to identify a few chemicals which showed potential on sorghum/pigeonpea intercrop systems. To further evaluate the efficacy of a few selected available herbicides and to examine the possibility of reducing heribicide rates, a trial was conducted in deep Vertisol during monsoon, 1978. The herbicides were applied only in 15 cm band on the crop rows and all the herbicide treatments were followed up with one hand weeding in between crop rows. The detailed treatments and the results are given in Table 6.

Table 6: Evaluation of different weed control methods in sorghum/pigeonpea intercrop in Vertisols, 1978.

Treatments*	Sorghum yields kg/ha	P.Pea yields kg/ha	Weed dry matter at sorghum harvest g/m²
Terbutryn (Band) + H.W.	5247	1117	94.0
Prometryn (Band) + H.W.	4196	1080	152.8
Ametryne (Band) + H.W.	4484	940	124.3
Fluchloralin (Band) + H.W.	5192	1379	93.8
H.W., 4 WAS	5217	1061	83.0
2 H.W., 3,6 WAS	5334	1204	27.0
Weed free	5497	1277	-
Weedy check	4564	469	232.8
C.D. at 5%	629	362	-

*H.W. = Hand weeding. WAS = Weeks after sowing.

It can be seen from the results that terbutryn applied at 0.3 kg/ha on the crop rows performed on par with the weed free treatment. However, prometryn and ametryn showed initial toxicity on sorghum. Fluchloralin performed equally good as terbutryn. The hand weeding given at 4 weeks after sowing yielded 5217 kg/ha which was on par with the terbutryn (band applied) + hand weeding (between rows) treatment. It may be concluded that the herbicide treatment was not economical when compared to one hand weeding in this particular season. However, the trial indicated that band application of herbicide to reduce costs is possible; and in areas where hand weedings are not feasible or labor is expensive terbutryn and fluchloralin may be applied as pre-emergence herbicides to provide initial check on weed growth.

2. Effect of Row Widths, Crop Density and Fertility on Weed Growth on Sorghum:

Earlier results indicated that higher crop density would contribute to minimising weed infestation. It was also noted that closer row spacings of sorghum would hinder the efficient inter row cultivations. Two trials were conducted (one each in Vertisol and Alfisol) to examine the effect of sorghum row widths and the relative plant population pressure in crop rows on the incidence of weeds at low and high fertility levels. The objective also include: to explore the possibility of reducing weeding efforts on the crop rows by manipulating crop density in the crop rows (without altering the optimum plant population). The treatments consisted of 3 row widths (45, 90, 135 cm - the population per ha was kept constant with closer intra row spacing), 2 fertility levels (20 N and 80 N) and 2 weeding treatments (row weeds present, row weeds absent). The detailed treatments and the results are presented in Tables 7 and 8 and Figs. 8 to 10.

In general, the weed population in the Vertisol experimental site was very poor when compared to Alfisol site. As the crop density was increased in the crop rows by widening crop rows to 90 and 135 cm there were reduction in crop yields under both fertility levels. However, there were considerable reduction in weed dry matter weights (from crop rows) as the crop density per row was increased. The reduction in crop yields were therefore due to crop-crop competition rather than crop-weed competition. The yield reduction was more severe under higher fertility level because the weed growth was also more under higher fertility level.

Even under weed free situation the yield reductions due to wider crop rows were observed. But at higher fertility, the yield levels under weed free situations were considerably superior than under higher fertility

Table 7: The influence of row widths and fertility on row weeds and sorghum yields on Vertisols, 1978.

Treatments		Low Fertility (20 N)			High Fertility (80 N)		
Row widths	Row weeds	Sorghum yield kg/ha	% reduction in yield	Weed dry-matter g/2 m row	Sorghum yield kg/ha	% reduction in yield	Weed dry-matter g/2 m row
45 cm	Yes	3335	-	45.9	4195	-	63.4
90 cm	Yes	2655	20	34.2	2892	33	49.6
135 cm	Yes	2530	24	21.1	3028	30	32.8
45 cm	No	3278	2	-	4065	12	-
90 cm	No	2623	21	-	3501	19	-
135 cm	No	2656	20	-	2945	32	-

Table 8: The influence of row widths and fertility on row weeds and sorghum yields on Alfisols, 1978.

Treatments		Low Fertility (20 N)		High Fertility (80 N)	
Row widths	Row weeds	Sorghum yield kg/ha	Weed dry matter g/2 m row	Sorghum yield kg/ha	Weed dry matter g/2 m row
45 cm	Yes	1642	106.7	2261	127.2
90 cm	Yes	2620	81.5	2719	104.4
135 cm	Yes	2113	72.7	3144	94.5
45 cm	No	2656	-	3825	-
90 cm	No	3252	-	4090	-
135 cm	No	3044	-	3311	-

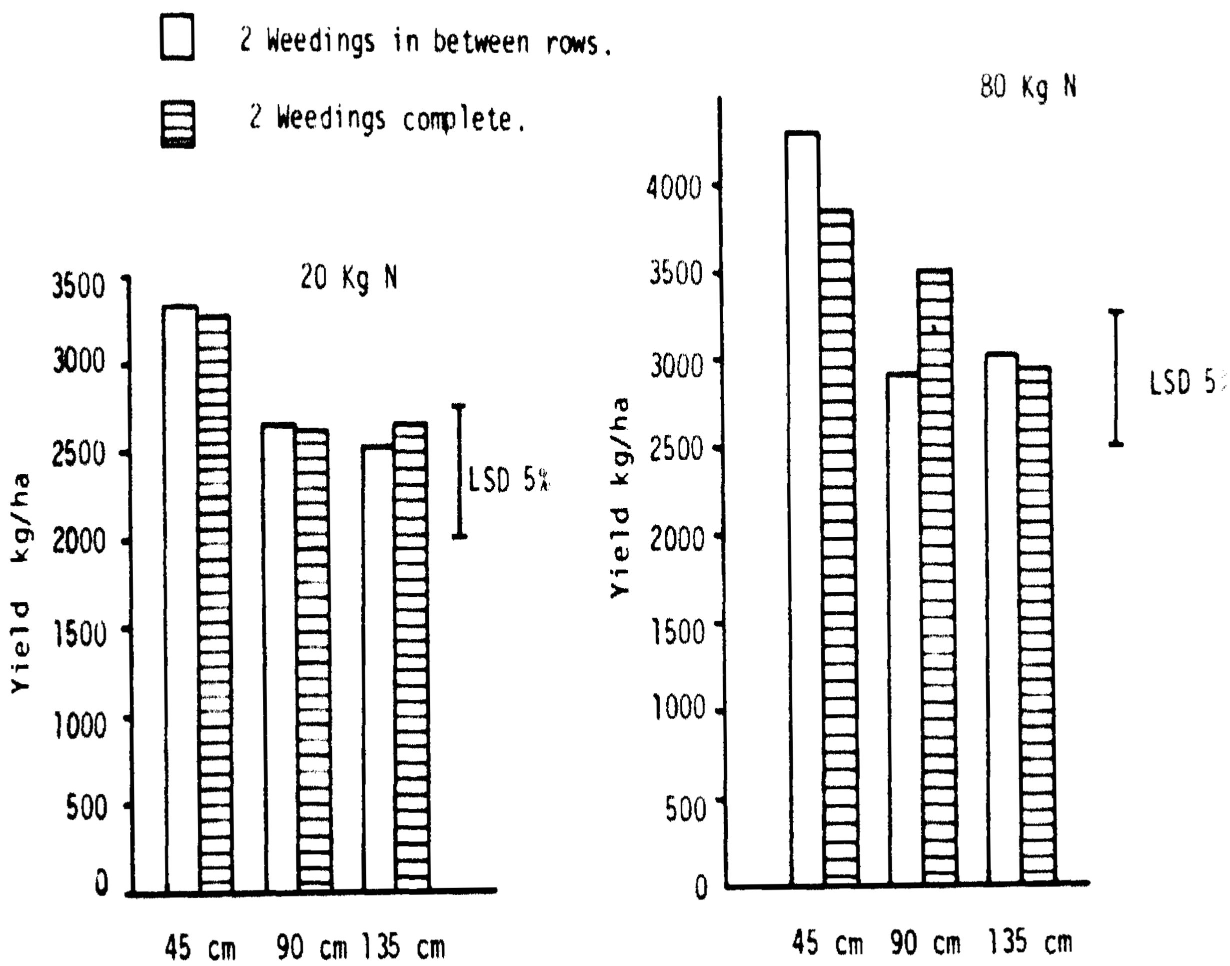

Fig. 8a. EFFECT OF ROW SPACINGS AND FERTILITY LEVELS ON SORGHUM YIELDS ON VERTISOLS AT ICRISAT, 1978.

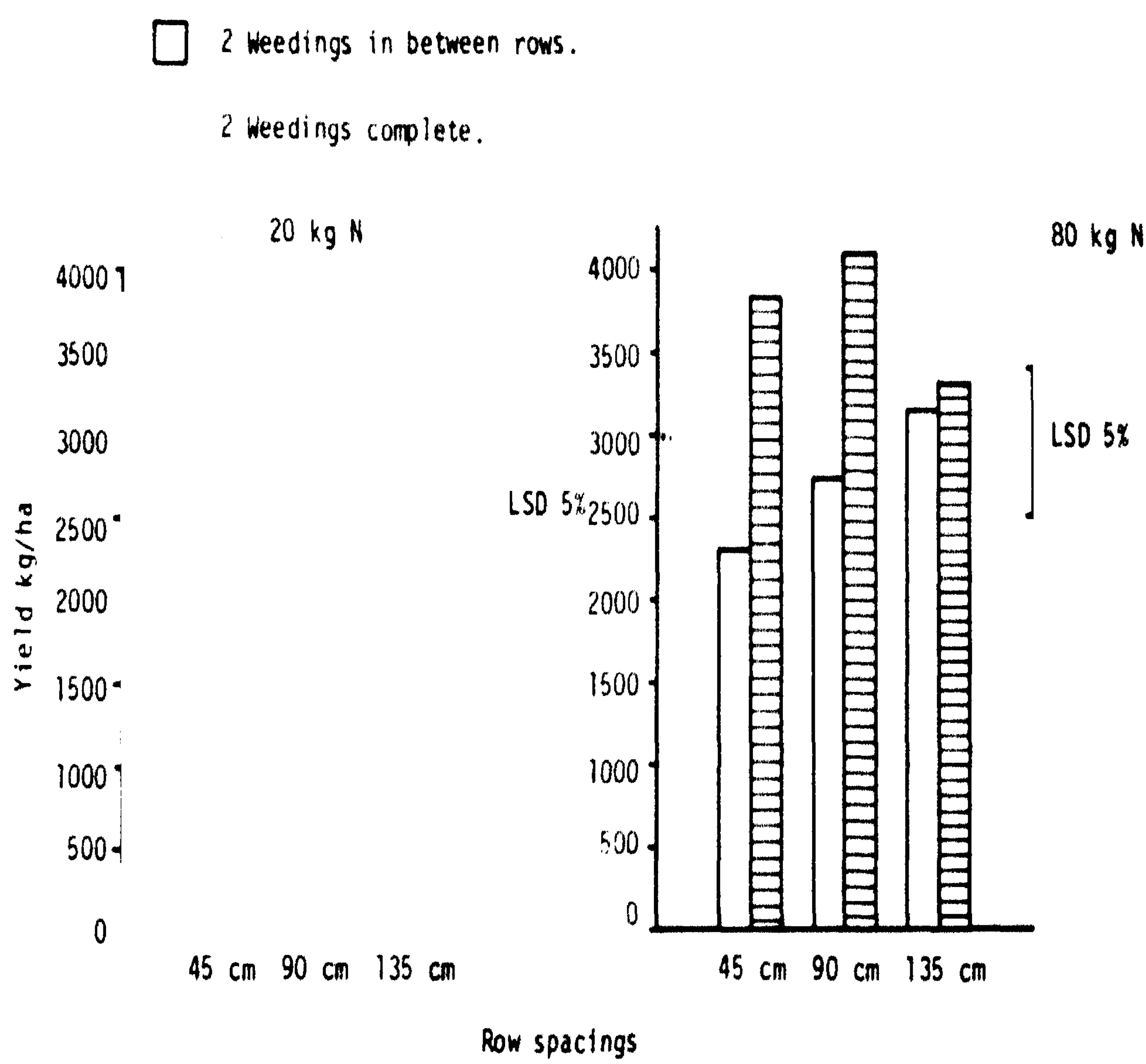

Fig. 8b. EFFECT OF ROW SPACINGS AND FERTILITY LEVELS ON SORGHUM YIELDS ON ALFISOLS AT ICRISAT, 1978.

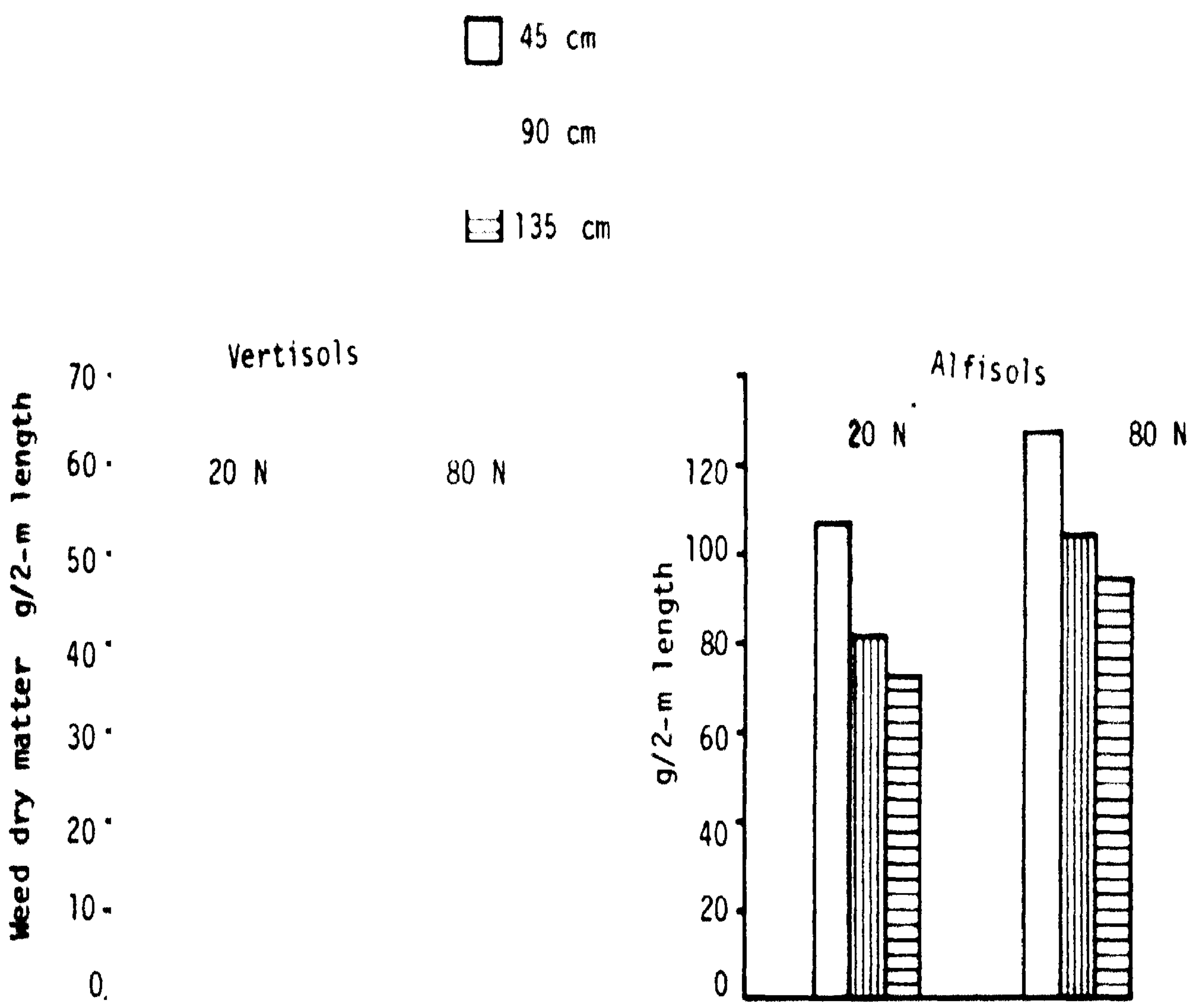

Fig. 9. EFFECT OF ROW SPACINGS AND FERTILITY LEVELS ON WEED GROWTH IN THE CROP ROWS AT ICRISAT CENTER, 1978.

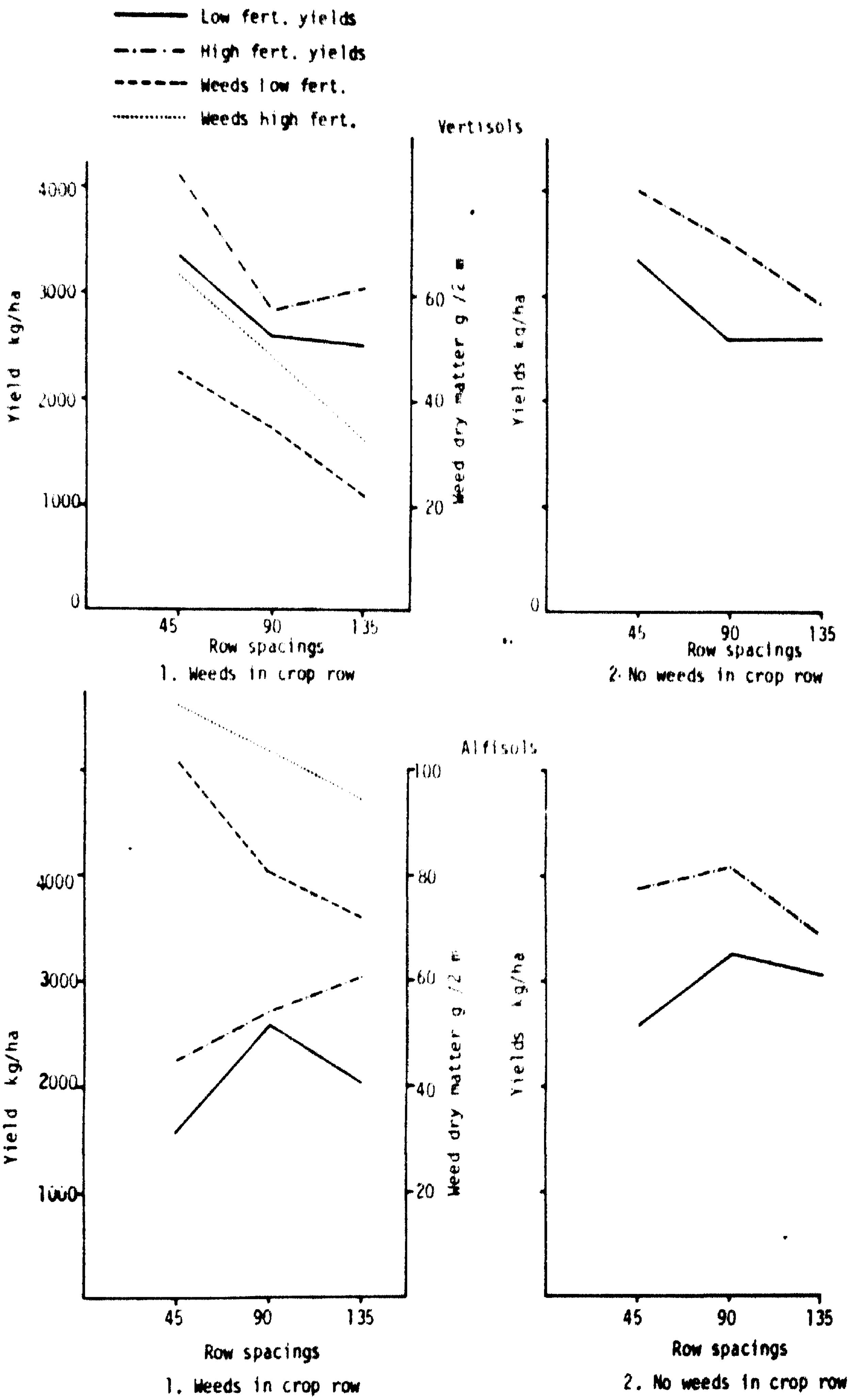

Fig. 10. EFFECT OF ROW SPACINGS, ROW WEEDS, AND FERTILITY LEVELS ON SORGHUM YIELDS AND WEED GROWTH AT ICRISAT CENTER, 1978.

and weedy situations. It may be noted that at higher fertility level row weeds cause considerable yield loss if row weeds are not controlled. Therefore only mechanical cultivation in between crop rows will not be sufficient to obtain optimum yields.

In Alfisols, the experimental field was infested with more weeds, but the plant population could not be kept up to the desired levels. Hence the overall yield levels were also low. However from the results (Table 8 and Fig. 8b) it was evident that sorghum yields were increased when planted in wider rows. Yield increases were observed under lower fertility when the rows were increased upto 90 cm, where as under higher fertility the higher yields were observed even with 135 cm row spacings. Also, when the plant populations were increased (by widening crop rows) there were marked decrease in weed growth, in crops rows. The losses caused by row weeds were to the extent of about 45 percent noticed by comparing the yields from weedy crop rows with weed free crop rows.

It may be observed that there are clear indications of reductions in row weed growth as the crop density in crop rows were increased. The magnitude of weed growth is higher at higher fertility; further the weed growth reduction due to increased crop density is also more at higher fertility level. However, there does not seem to be much scope for going for wider rows as increasing in row width causes reduction in crop yields. However, thse studies will be continued for one more season mainly to understand the effect of row weeds on crop yields.

3. <u>Chemical Weed Control for Monsoon Cropping in Deep Vertisol</u>:

May pre-emergence herbicides which showed promise in controlling early weed growth in deep Vertisols during monsoon have been earlier identified. A trial was conducted to further evaluate the efficacy of manual and chemical methods of weed control for monsoon cropping of maize in deep Vertisols and also to examine the possibilities of economising the cost of weeding methods. Different rates of atrazine and alachlor were evaluated alone and in combination with one hand weeding (4 weeks after planting). Further, the performance of blanket application of herbicides were compared with band application only on the crop rows. The detailed treatments and the results are presented in Table 9.

It was observed that the band application of herbicide was not very successful as the treatment failed to check the weed growth in between crop rows. The maximum yield was obtained with 3 hand weedings while atrazine + alachlor (blanket applied) followed with one hand weeding resulted in 1299 kg/ha of maize yields. The one hand weeding treatment was superior to band application of herbicides. Band application of herbicide followed with one hand weeding yielded similar to that obtained with one hand weeding only. Therefore, there does not seem to be any additional advantage with herbicide application. However, blanket application of herbicide performed better and the yields obtained were similar to those with 2 hand weedings treatment. It is therefore, understood that in the areas where hand weedings are not feasible or expensive, herbicides can provide very good initial check on weed growth in deep Vertisols during monsoon season.

Table 9: Evaluation of different weed control for rainy season cropping of maize on Vertisols, 1978.

Treatments	Maize yield kg/ha	Weed yield g/m^2	Height at maturity (cm)
Atrazine + Alachlor blanket (1.5 + 1 kg/ha)	1157	296.5	199.1
Atrazine + Alachlor + H.W. (1.5 + 1 kg ai)	1299	49.4	187.4
Atrazine + Alachlor Band (0.5 + 0.3 kg ai/ha)	549	433.5	159.0
Atrazine + Alachlor + H.W. bet. (0.5 + 0.3)	776	133.3	162.1
H.W. 4 WAS	854	217.1	162.2
2 H.W. 3,6 WAS	1157	24.5	168.4
3 H.W. 3,6,8 WAS	1572	-	202.0
Check	257	953.3	148.0
C.D. at 5%	273	158	15.5

Chickpea grown after maize harvest did not show any phytotoxicity symptoms indicating that atrazine and alachlor did not leave any residues toxic enough to post-monsoon planted chickpeas.

4. Effect of Different Factors on Weed Growth:

Various biological, cultural and physical factors affect the crop-weed associations. It is necessary to understood and quantify the effect of these factors to shift the crop-weed balance towards more productive crop growth. During the year two factors weed density (biological) and shading levels (physical).

4.1 Weed Density:

A trial was conducted in deep Vertisols to examine the competitive effect of individual weeds in different density on the growth and yield of sorghum. Two weeds *Digitaria ciliaris*, a grass and *Corchorus olitorius* a dicot were planted along with sorghum in different densities. The crop and weed growth observations were taken frequently to determine the competitive effect of these two weeds on sorghum. The detailed treatments and the results are presented in the Table 10 and Figs 11a and 11b.

It was observed that increase in weed density adversely affected crop yields in case of both the weeds. But the effect was more pronounced with *Corchorus* than with *Dgitaria*. Though the yield reductions were not significant from 200 to 400 weeds/sq.m the competitive effect of *Corchorus* was reflected in further reductions of the sorghum yields. The sorghum yield reductions were significant till the *Digitaria* density were increased upto 100 plants/sq.m and from there on there were no significant yield reductions, unlike *Corchorus*. *Digitaria* was more competitive to sorghum when compared to *Corchorus*, especially at lower density, perhaps because of similar growth habit as that of sorghum. *Corchorus* being a dicot has different growth habit and did not offer severe competition as *Digitaria*. Therefore, in lower weed density levels the yield loss with *Digitaria* is more than that with *Corchorus*.

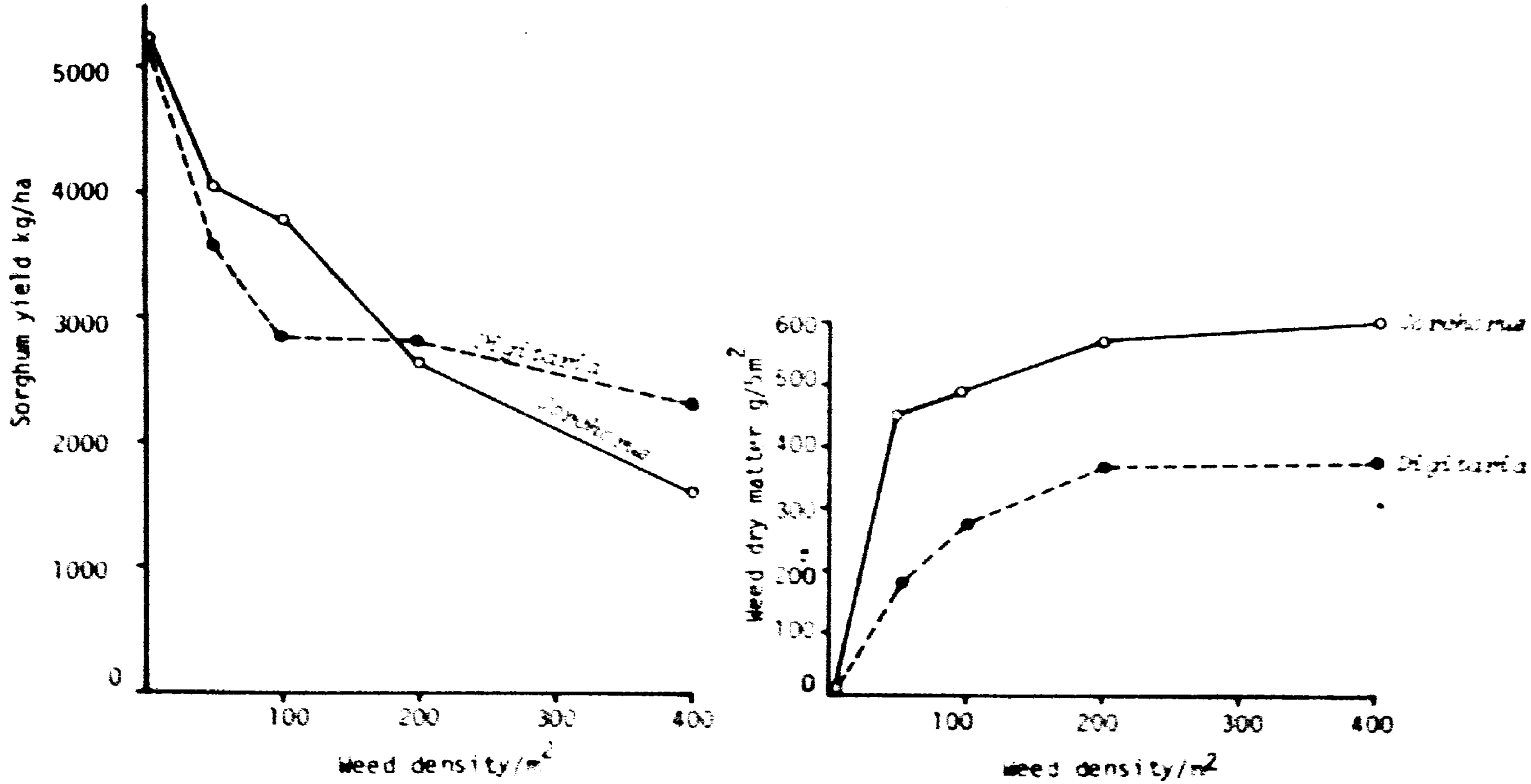

Fig. 11a. EFFECT OF DIFFERENT DENSITIES OF CORCHORUS AND DIGITARIA ON SORGHUM AND WEED YIELDS ON VERTISOLS AT ICRISAT CENTER, 1978.

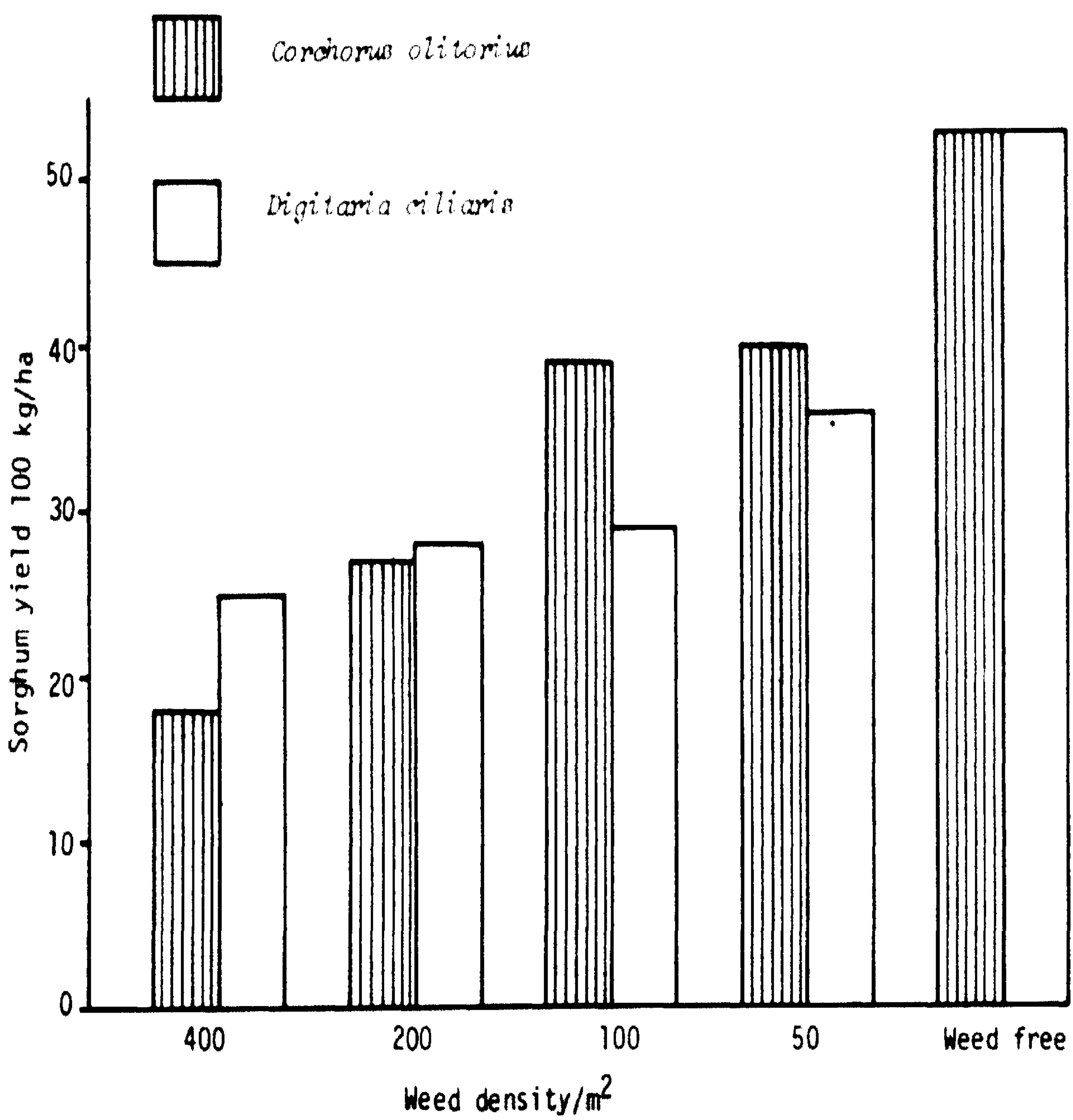

Fig. 11b. EFFECT OF WEED DENSITY ON THE YIELD OF SORGHUM ON VERTISOLS, 1978.

The data on weed dry matter weights indicate that as the density was increased to a certain level (200/sq.m) there was increase in weed dry matter but further increase in density did not influence the dry matter weights. This is probably due to weed-weed competition at such a high density level resulting in poor weed growth. This observation agrees with sorghum yield data in that increasing weed density above certain levels (200 pl/sq.m) did not affect sorghum yields further.

Table 10: Effect of weed density on growth and yield of sorghum on Vertisols, 1978

Weed density	*Corchorus olitorius*			*Digitaria ciliaris*		
Plants/sq.m.	Sorghum yield kg/ha	Fodder weight gm/plot	Weed dry matter gm/0.5 M^2	Sorghum yield kg/ha	Fodder weight gm/plot	Weed dry matter gm/0.5 M^2
400	1696	2733	600	2456	2866	378
200	2670	2866	572	2850	3400	360
100	3883	2933	499	2890	3400	283
50	4013	3800	451	3616	3733	192
Weed free	5273	4000	-	5273	4000	-
C.D. at 5%	1913	*N.S.	245	799	*N.S.	94

*N.S. = Not significant

4.2 Effect of Shading on Weed Growth:

As light is one of the important physical factors operating in crop-weed balance, manipulation of light would be one of the approaches to obtain better management of weeds. It is presumed that providing selective shading through optimum crop/crops canopy would help in managing certain weeds. To examine the growth response of some selected weeds to different levels of available light (shading) a preliminary trial was conducted in Alfisol during kharif, 1978. Different levels of shading were simulated by the use of bamboo shade frames having different sized perforations. The bamboo frames approximately allowed 10, 20, 30 percent available light to pass through. 10-15 day old seedlings of *Cyperus rotundus*, *Digitaria ciliaris*, *Acanthospermum hispidum* and *Celosia argentea* were transplanted to 2 x 6 m plots in Alfisols and allowed to grow till their reproductive growth period. Each plot had about 70 plants of individual weeds where the weed to weed competition was avoided. Different bamboo shades were placed over the growing weeds throughout the season permitting only the weeds of intercept the known amount of light during their life cycle. The light coming through side-ways were prevented by growing tall growing sorghum before the start of the experiment. Growth observations on weeds were recorded frequently along with the frequent solarimeter readings (in collaboration with agroclimatologists) to record the photosynthetically active radiation transmitted through the shade frames. The results are presented in Tables 11 to 14 and Figs. 12 to 19.

All the test weed species are sensitive for shading. The data on dry matter production at the end of the life cycle indicate that shading has affected the normal growth of weeds. There was marked reduction in shoot and tuber dry weights of *Cyperus* as the available light intensity was reduced. Similarly new tubers and shoots formed were also reduced substantially when the shadings were provided. A small percent of shading affected the dry matter production considerably indicating that *Cyperus* is highly shade sensitive when compared to other weeds. While control (no shade) plants produced about 25 new tubers/plant the 90% shaded plants could produce only about 2 tubers/plant indicating the potential of shading in reducing the propagation of this particular weed.

Cyperus, *Digitaria* and *Acanthospermum* also respond to shading as does *Cyperus* and the data on final dry matter indicate that the growth of these weeds were substantially affected when grown under 90% shading. *Celosia* seems to be more tolerant than the order two. Though in the early stages of growth the shaded plants were taller (especially *Digitaria)* than the control, later in the season the control plants had greater plant heights. The plants grown under shade were considerably shorter. There were about 25-30% mortaility in shaded plants and *Celosia* and *Acanthospermum* showed about 10% mortality even under 70% shading. The effect of shading on seed production of these annual weeds were very significant, 90% shading almost prevented the seed production while 30% light interception resulted in only 25 to 50% seed production. Shading therefore has considerable significant in preventing multiplication of weed community. Though the small amount of shading did not have much effect on leaf area index, at higher shading levels the weeds showed considerable reduction in leaf area index also.

Table 11: Effect of different levels of shading on the growth of *Cyperus rotundus* on Alfisols, 1978.

Photosynthetically Active Radiation (Microeinsteins/cm^2/sec)	Numbers of tubers produced per 70	Weight of tubers in gms	Number of shoots per 70	Weight of shoots in gms
1. 131 (10%)	287	151.3	212	158.5
2. 239 (20%)	603	334.2	343	257.3
3. 418 (32%)	889	660.0	505	348.3
4. 1287 (Control)	1672	1308.5	751	723.5
C.D at 5%	90.4	208.7	122	129.8

Table 12: Effect of different levels of shading on the growth of *Digitaria ciliaris* on Alfisols, 1978.

Photosynthetically Active Radiation (Microeinsteins/cm^2/sec)	Drymatter in gms	Plant height in cms	% seed production	% Mortality	Leaf Area Index
1. 131 (10%)	837.5	76.2	10	20.6	0.25
2. 239 (20%)	879	80.3	15	19.8	0.31
3. 418 (32%)	1269	95.75	28.5	-	0.79
4. 1287 (control)	1918	101.95	100	-	0.89
C.D at 5%	618	*N.S.	21	2.1	0.2

*N.S. = Not significant

Table 13: Effect of different levels of shading on the growth of *Celosia argentea* on Alfisols, 1978.

Photosynthetically Active Radiation (Microeinsteins/cm^2/sec)	Dry matter in gms	Plant height in cms	% Seed Production	% Mortality	Leaf Area Index
1. 131 (10%)	1989	102.8	14.5	23.9	2.05
2. 239 (20%)	2057	115.4	19.5	19.6	2.97
3. 418 (32%)	2746	134.3	55.0	6.4	3.5
4. 1287 (Control)	3309	158.6	100	-	3.8
C.D. at 5%	790	28	27	2.7	1.2

Table 14: Effect of different levels of shading on the growth of *Acanthospermum hispidum* on Alfisols, 1978.

Photosynthetically Active Radiation (Microeinsteins/cm^2/sec)	Dry matter in gms	Plant height in cms	% Seed Production	% Mortality	Leaf Area Index
1. 131 (10%)	248.7	34.4	10	22.1	0.30
2. 239 (20%)	341.4	39.4	15	11.4	0.33
3. 418 (32%)	593.4	52.7	51	2.8	0.55
4. 1287 (Control)	1114.1	68.3	100	-	0.75
C.D. at 5%	177.2	8.3	20	4.9	0.54'

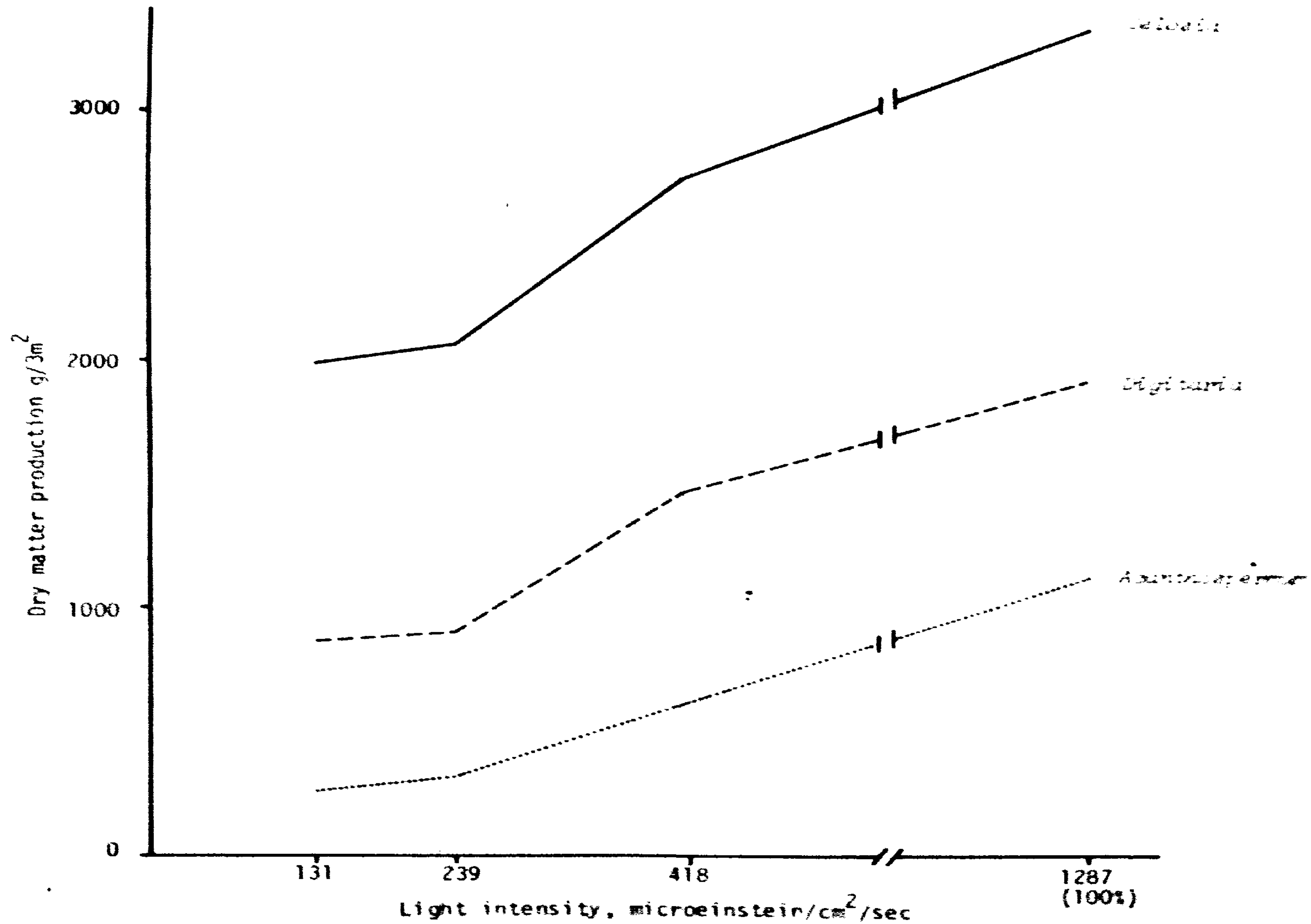

Fig. 12. EFFECT OF DIFFERENT LEVELS OF LIGHT TRANSMISSION ON GROWTH OF 3 WEEDS ON ALFISOLS, 1978.

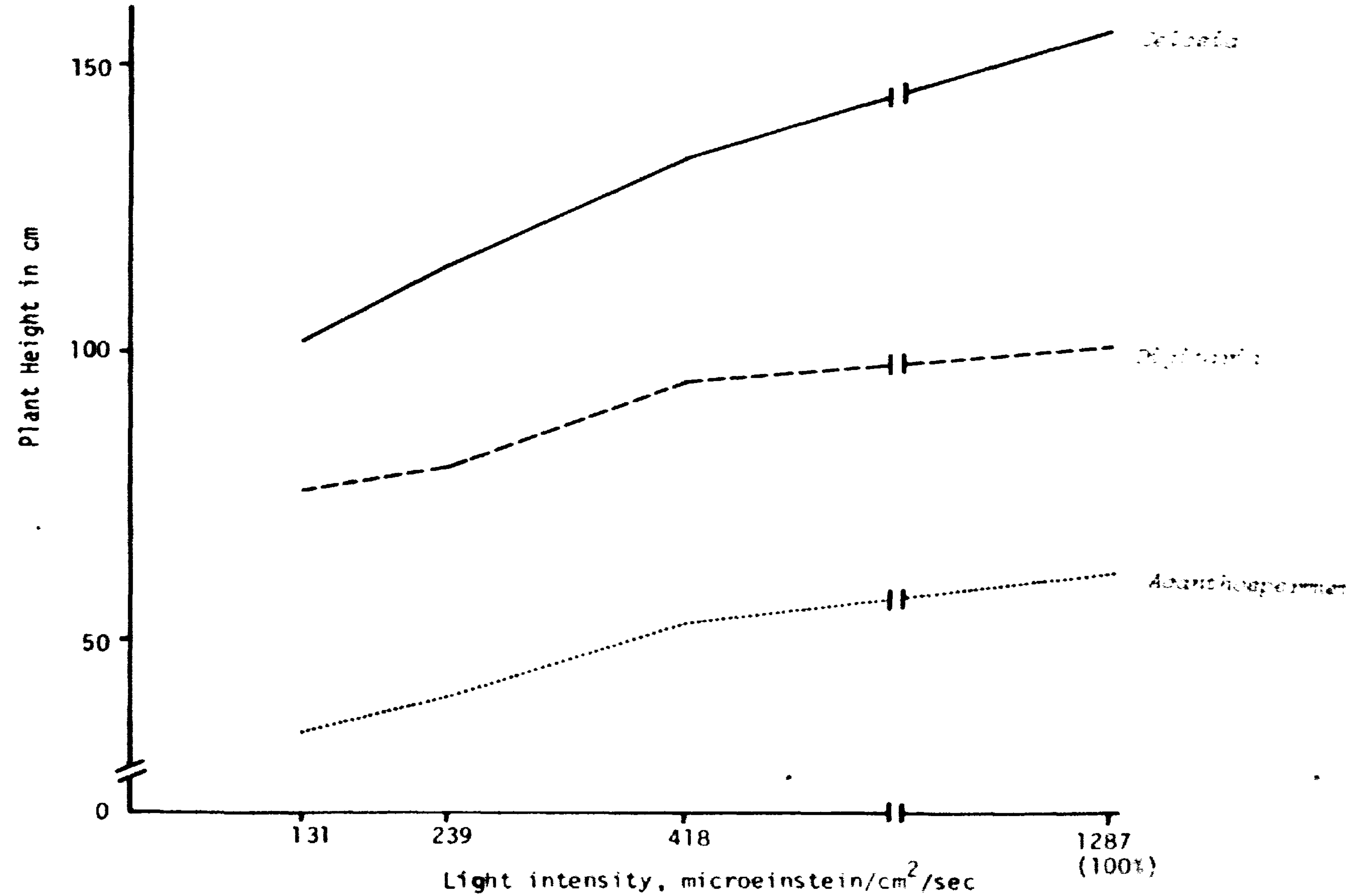

Fig. 13. EFFECT OF DIFFERENT LEVELS OF LIGHT TRANSMISSION ON THE HEIGHT OF 3 WEEDS ON ALFISOLS, 1978.

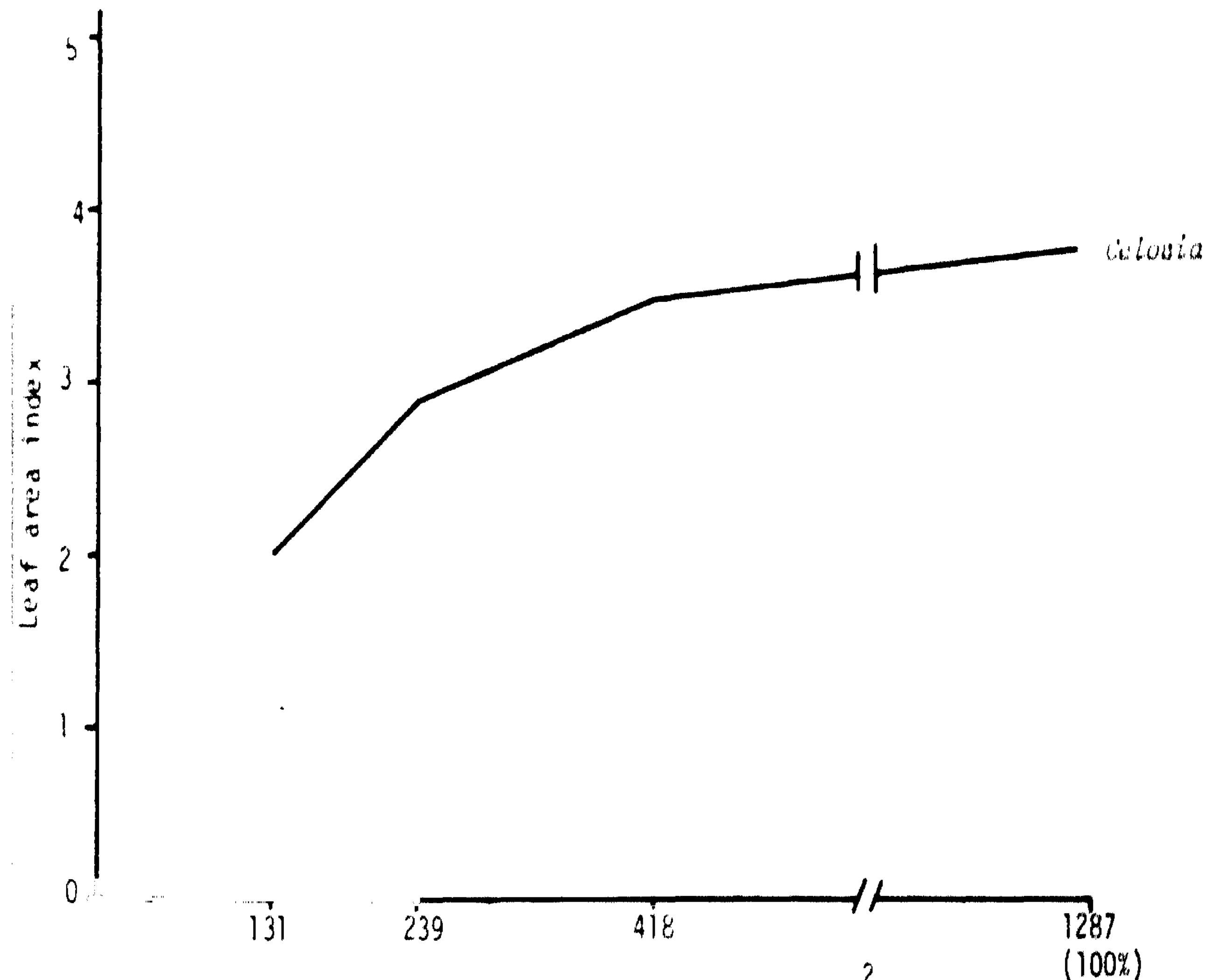

Fig. 14. EFFECT OF DIFFERENT LEVELS OF LIGHT TRANSMISSION ON THE LEAF AREA INDEX OF CELOSIA ON ALFISOLS, 1978.

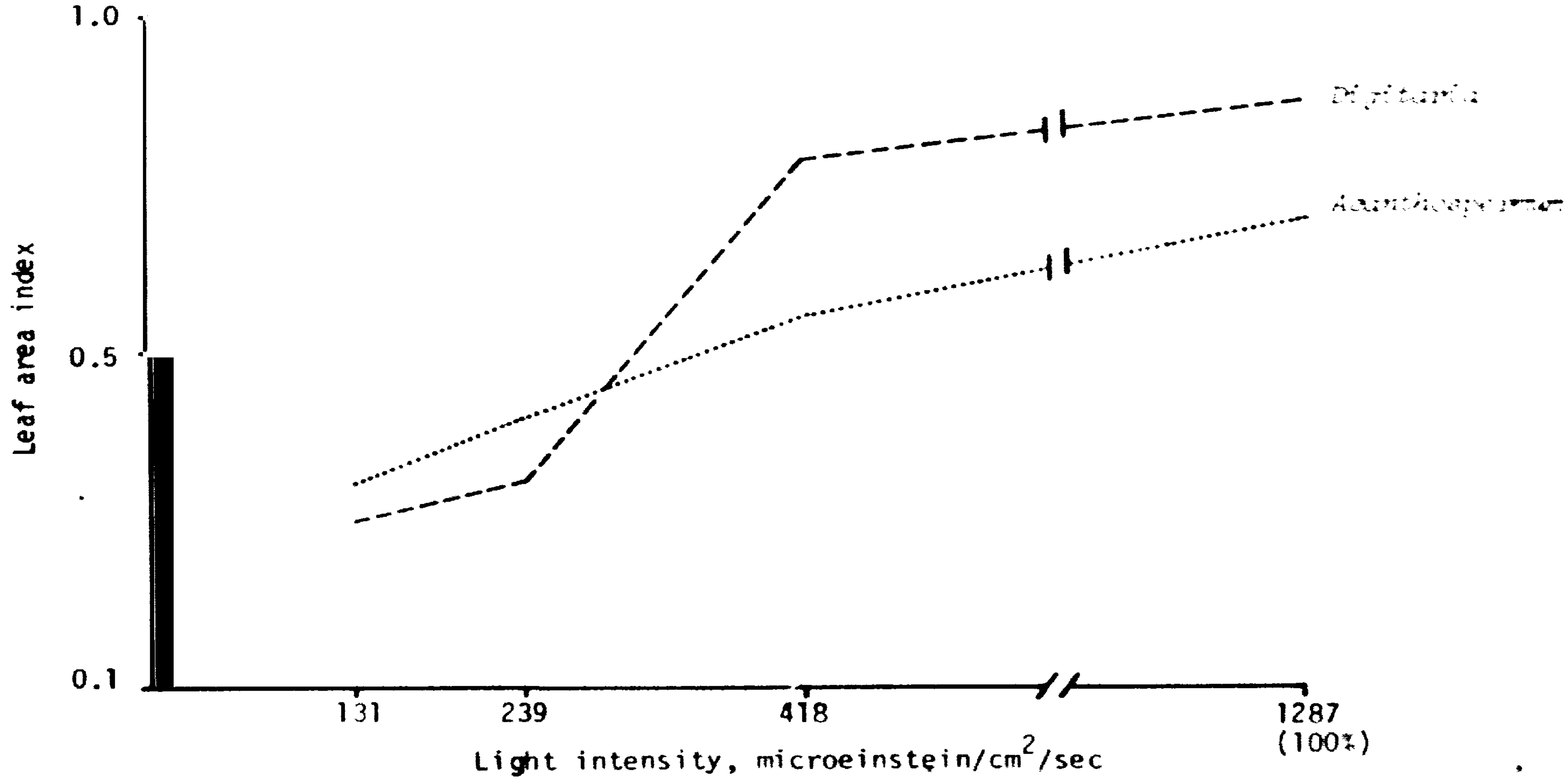

Fig. 15. EFFECT OF DIFFERENT LEVELS OF LIGHT TRANSMISSION ON LEAF AREA INDEX OF DIGITARIA AND ACANTHOSPERMUM ON ALFISOLS, 1978.

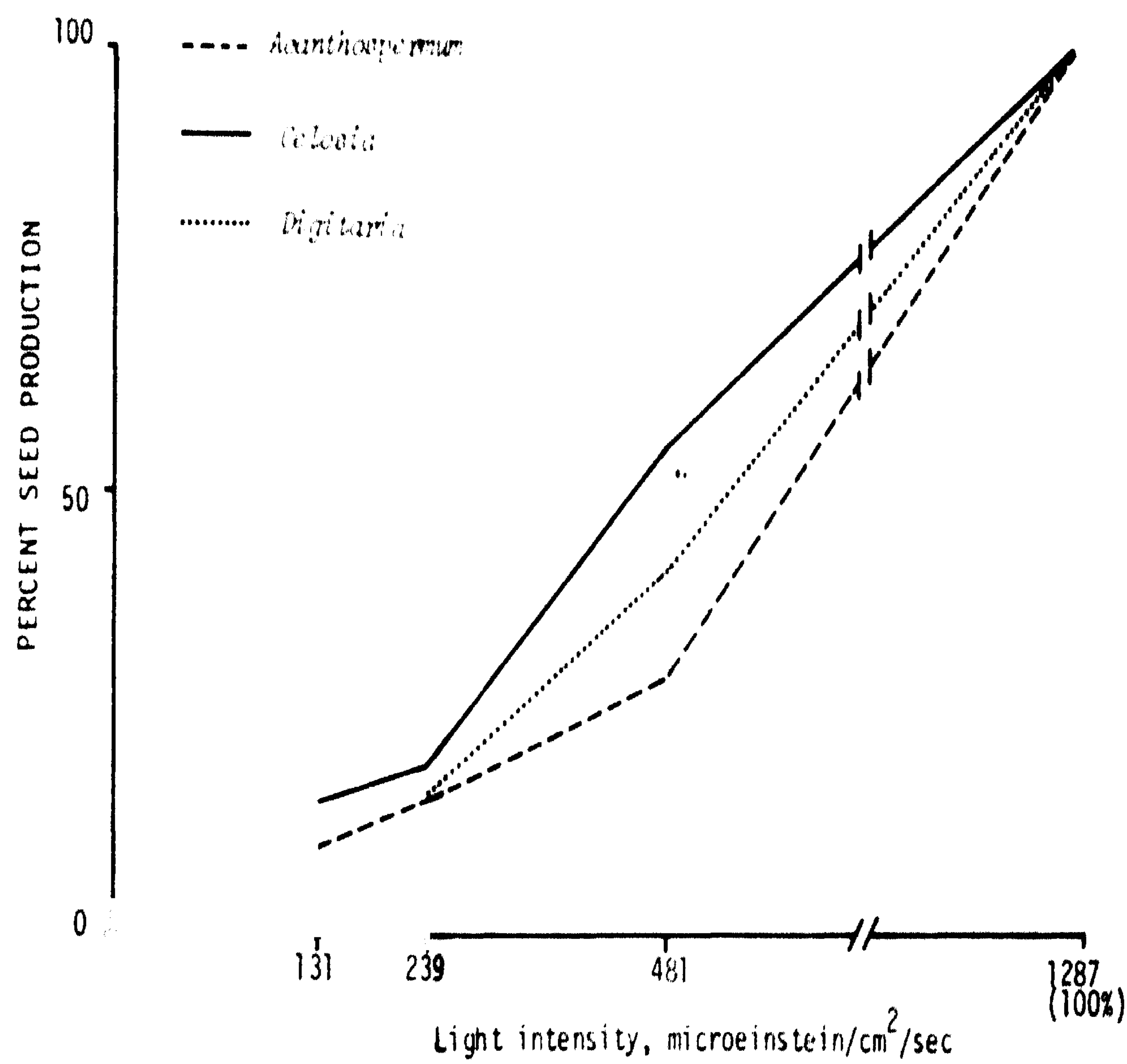

Fig. 16. EFFECT OF DIFFERENT LEVELS OF LIGHT TRANSMISSION ON THE SEED PRODUCTION OF 3 WEEDS ON ALFISOLS, 1978.

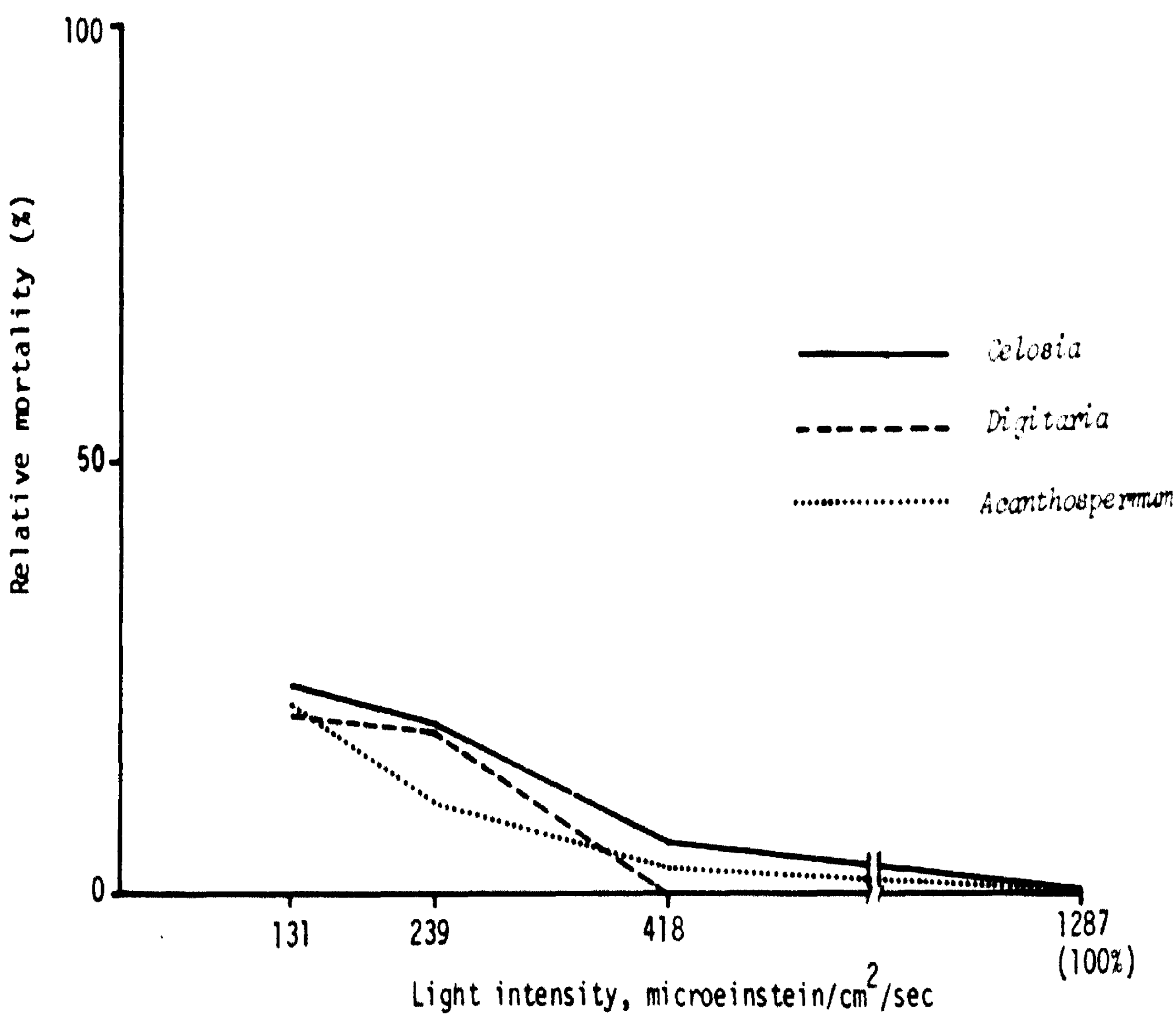

Fig. 17. EFFECT OF DIFFERENT LEVELS OF LIGHT TRANSMISSION ON THE RELATIVE MORTALITY OF 3 WEEDS ON ALFISOLS, 1978.

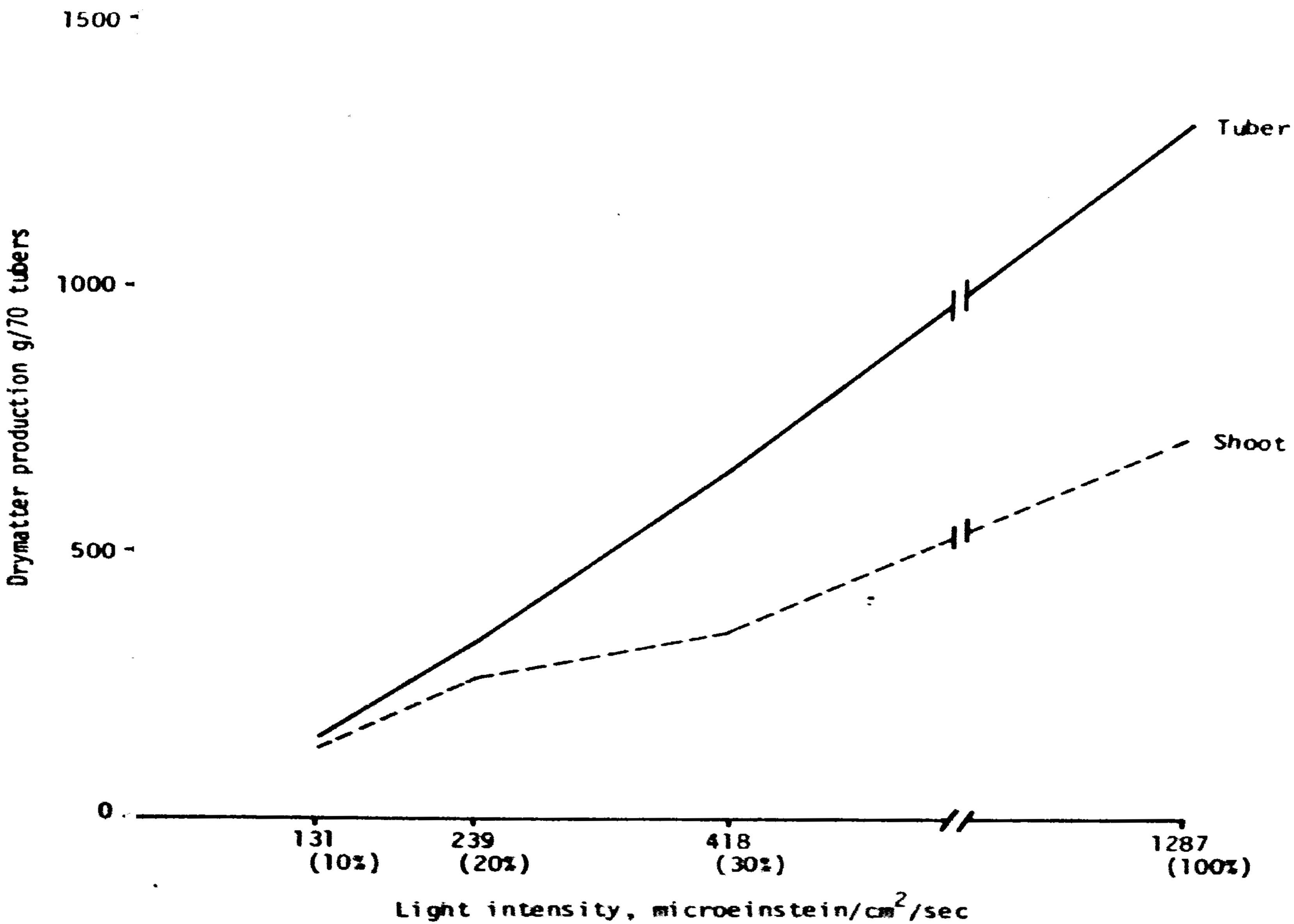

Fig. 18. EFFECT OF DIFFERENT LEVELS OF LIGHT TRANSMISSION ON CYPERUS GROWTH ON ALFISOLS, 1978.

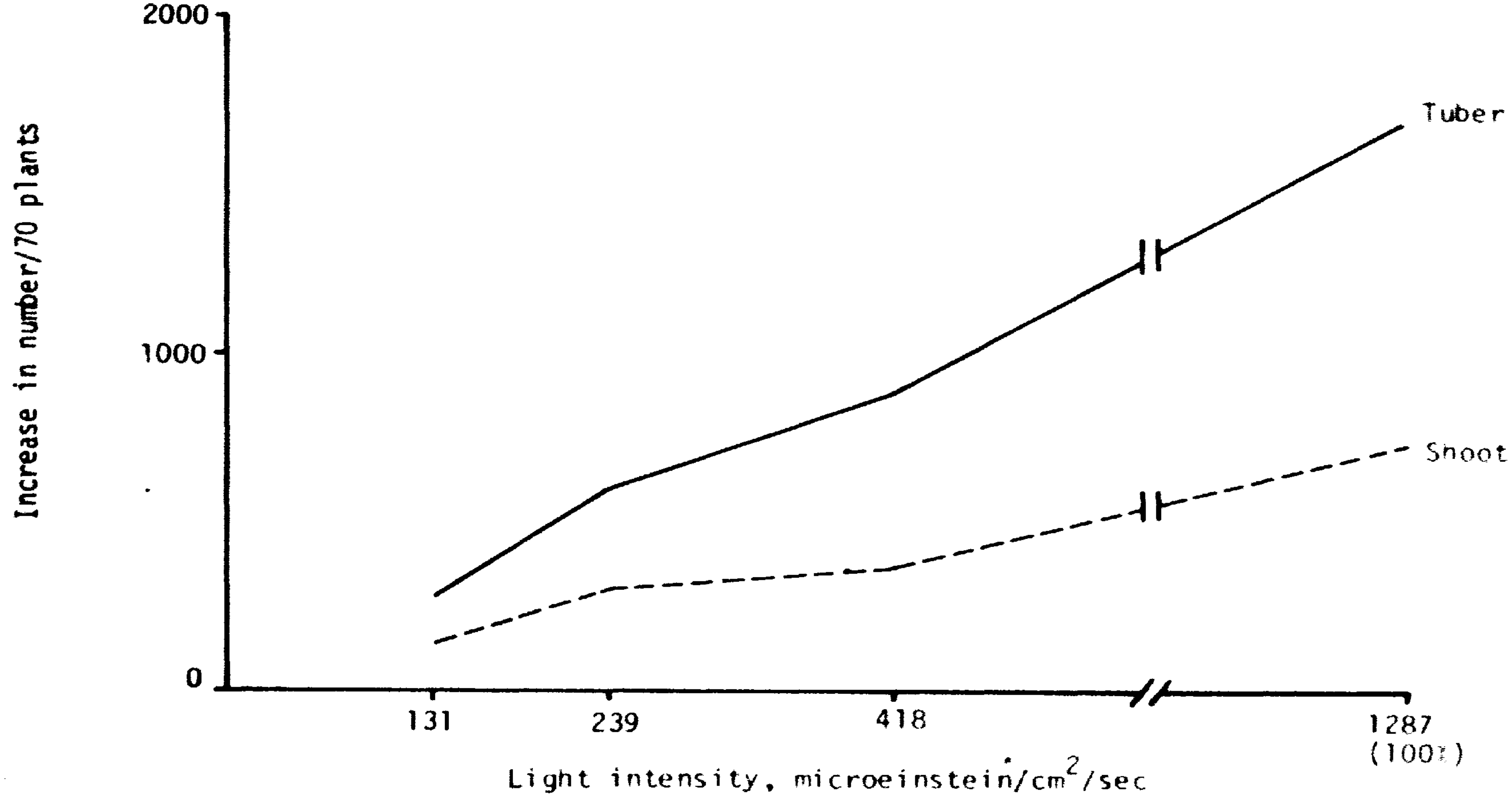

Fig. 19. EFFECT OF DIFFERENT LEVELS OF LIGHT TRANSMISSION ON THE REGENERATION OF CYPERUS ON ALFISOLS, 1978.

This preliminary study indicate that the concept of smother cropping to manage weeds operates mainly through shading of weeds by additional crop canopy of mungbean or cowpea. Further studies to determine the response of other weeds to different levels of shading have been planned. Also, simulation of different crop canopies to provide optimum shading effects on weeds needs to be further examined.

5. Effect of Different Soil Management Practices on the Intensity and Composition of Weed Seeds in the Soil:

Different management systems affect weed seed germination and weed seedlings establishment. A long term experiment was started during the year to monitor the tendency of weed emergence and weed seed depletion from the soil under different soil and crop management system in comparison with traditional system. The objectives also include the measurement of potential weediness (identity as well as numbers) as affected by different management treatments.

Soil samples from two depths (0-15 cm and 15-30 cm) were taken from experimental plots of BW5 and RW3 where different soil management treatments - broad ridges, narrow ridge and flat beds are being evaluated. Soils from same depths of a plot were bulked together and placed in earthen pots (32 x 16 cm). The pots were watered regularly to stimulate weed seeds to germinate. As and when the weeds appear, they were identified, counted and pulled out. The pots will be preserved till no more weeds emerge and all the weed seed reserves in the soil depleted.

Figs. 20 and 21 show the first year results of the study. The first flush of weeds emerged during the month of June immediately after first monsoon showers. Subsequently, the new flushes of weeds emerged after the previous flushes were removed. But, the intensity of later weed germination were less when compared to previous flushes. However, during all the months seeds germinated in large number from 0-15 cm layers. As the season progressed there was a declining trends in weed seed germination, but during November (begnning of post rainy season) there was again an increase in weed germination, perhaps due to the germination of post-rainy season weeds.

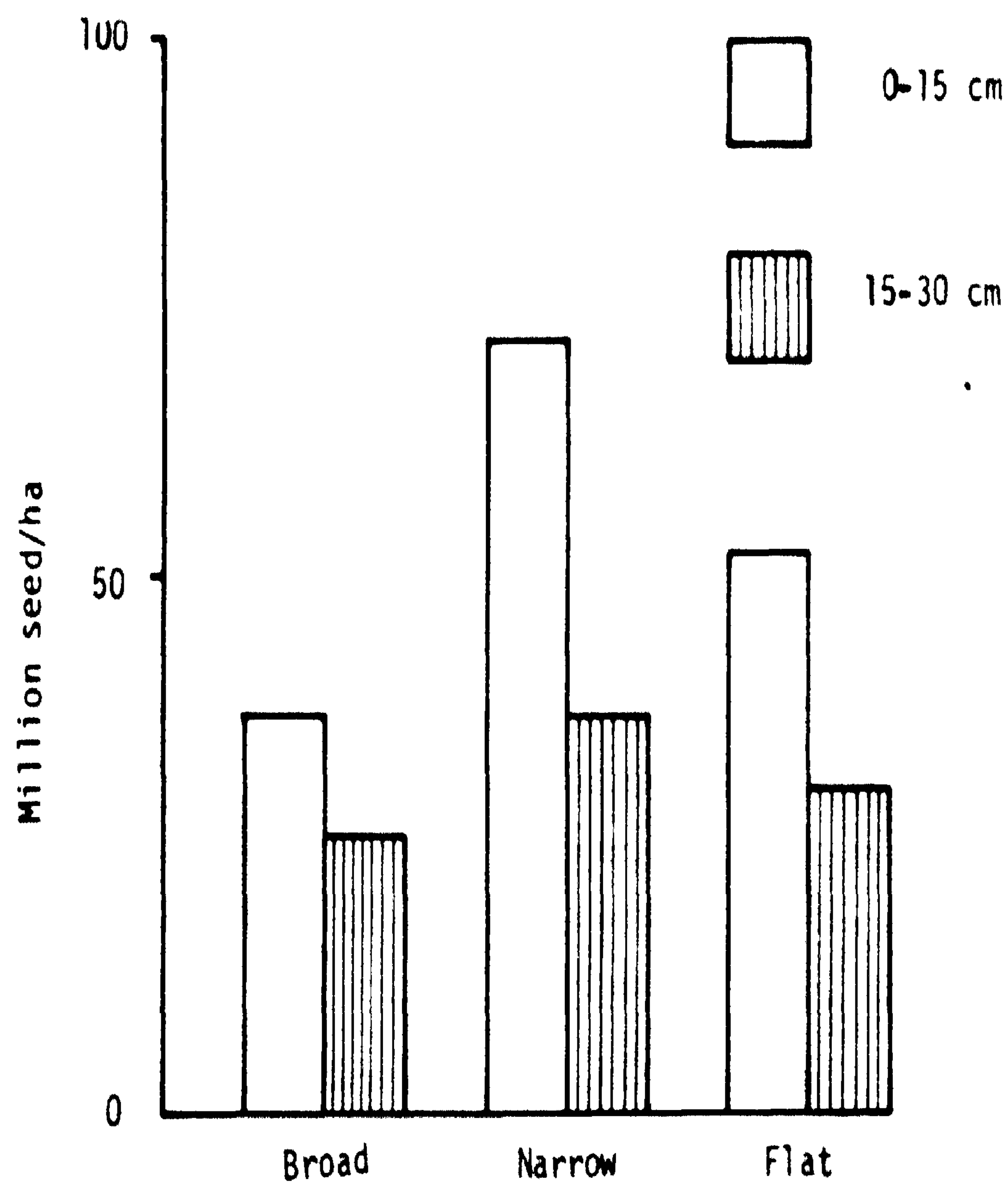

Fig. 20. EFFECT OF DIFFERENT TYPES OF SEED BEDS ON TOTAL WEED EMERGENCE DURING MONSOON ON VERTISOLS, 1978.

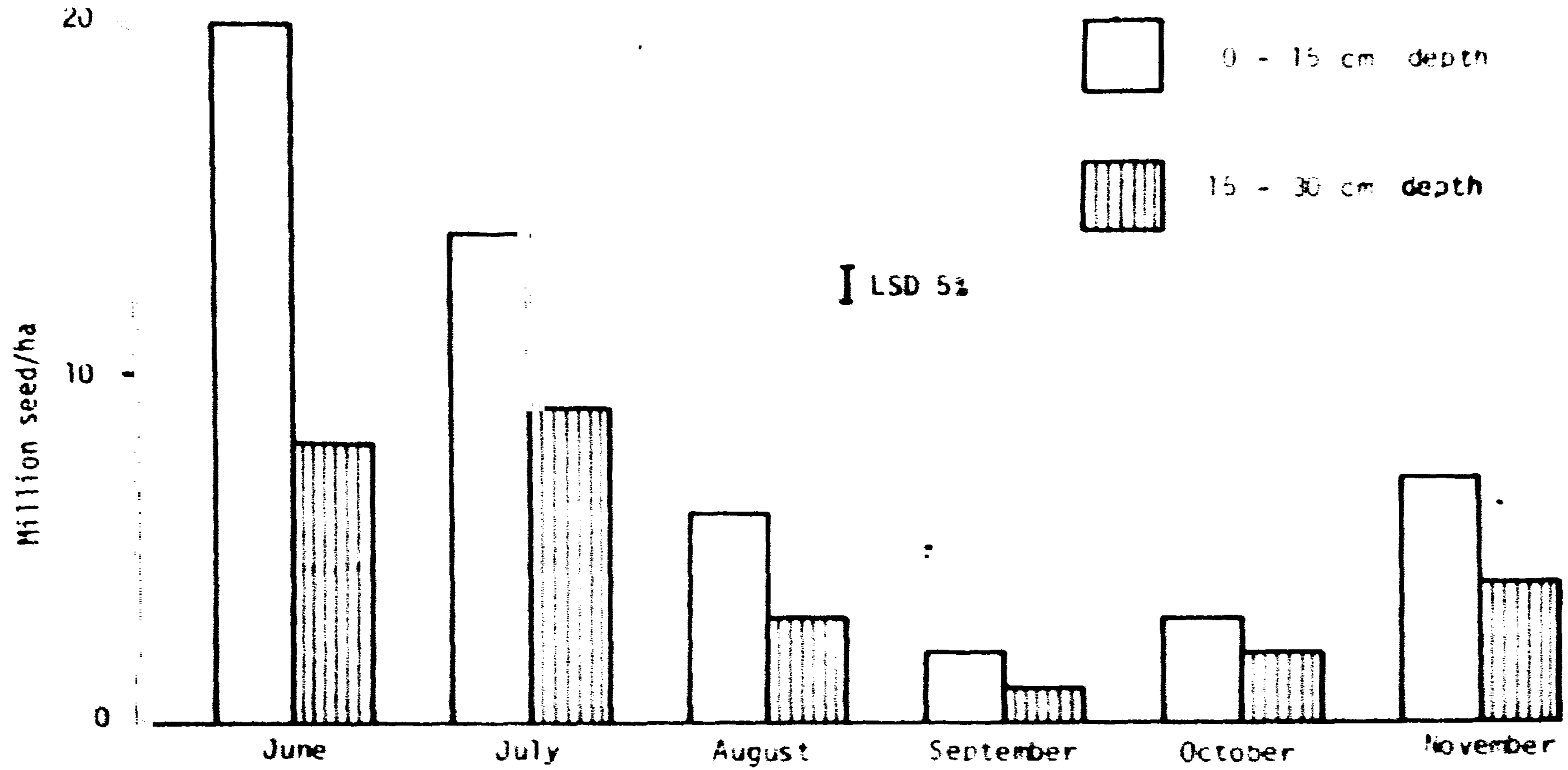

Fig. 21. TOTAL WEED SEED EMERGENCE DURING DIFFERENT MONTHS OF THE CROP SEASON (MONSOON) ON VERTISOLS, 1978.

Among the land management treatments, soil samples collected from narrow ridges, showed higher number of weed seedlings followed by Flat and Broad bed systems. However, it should be noted that the data was from only one season and the final conclusion could be drawn only when all the weed seeds in the soil samples would be depleted.

6. On-Farm Weed Research:

A few experiments were conducted in farmers fields at different locations mainly to investigate the potential of introducing improved weed control methods to small farmers of Indian SAT. The objectives also include to determine the success of farmers own methods of weed control in preventing crop yield losses due to weeds and to see whether improved methods of weed control involving the use of herbicide are feasible under the existing system of the small farmer Groundnut and sorghum were the crops selected. The treatments included farmers method of weed control, herbicides, herbicide + hand weeding, farmers method + herbicide at low (20 N) and high (80 N) fertility levels. The villages selected for studies were Dokur, Kanzara, Pocharam and Aurupalle. The land preparation, planting, and other management practices were done by the farmers as usual.

The detailed results and discussion on the experiments are presented as a thesis submitted to the University of Reading by Ellis P. Davies. Only some general observations are presented here

It was observed that the farmer in these villages, generally practices good weed control and that weed are not a serious problem on the farmers fields under the existing farming systems. It was noticed that the weeds are in greater quantity on the research farm than in the farmers' fields (Table 15). This is perhaps due to favourable environment existing in research station like having higher fertility, practicing double cropping and the use of irrigation.

The use of herbicides in addition to the farmers traditional methods was not economically feasible despite giving higher yields and lower weed dry matter. The improved weed control methods were not necessary for the farmers under their existing circumstances. Though this may change if they should adopt better agronomic practices which result in higher yields.

Table 15. The quantity of weeds at ICRISAT Center and at the neighbouring farmer's fields at harvest time of sorghum.

Sample No.	Research farm g/m^2	Farmer's fields g/m^2
1.	38.8	10.02
2.	22.8	14.85
3.	29.2	4.20
4.	24.0	15.00

The use of pre-emergence herbicides appears to be more feasible under the higher value crop-groundnut than the lower value food crop like sorghum. However, if herbicides are to be economically feasible under the existing farmers' situation then much higher yields than the farmers' present levels must be achieved before this is possible.

The use of fertilizer is a means of overcoming weed competition in sorghum and herbicides are possibly more economically feasible under high fertilizer rather than low fertilizer inputs (Figs. 22-25).

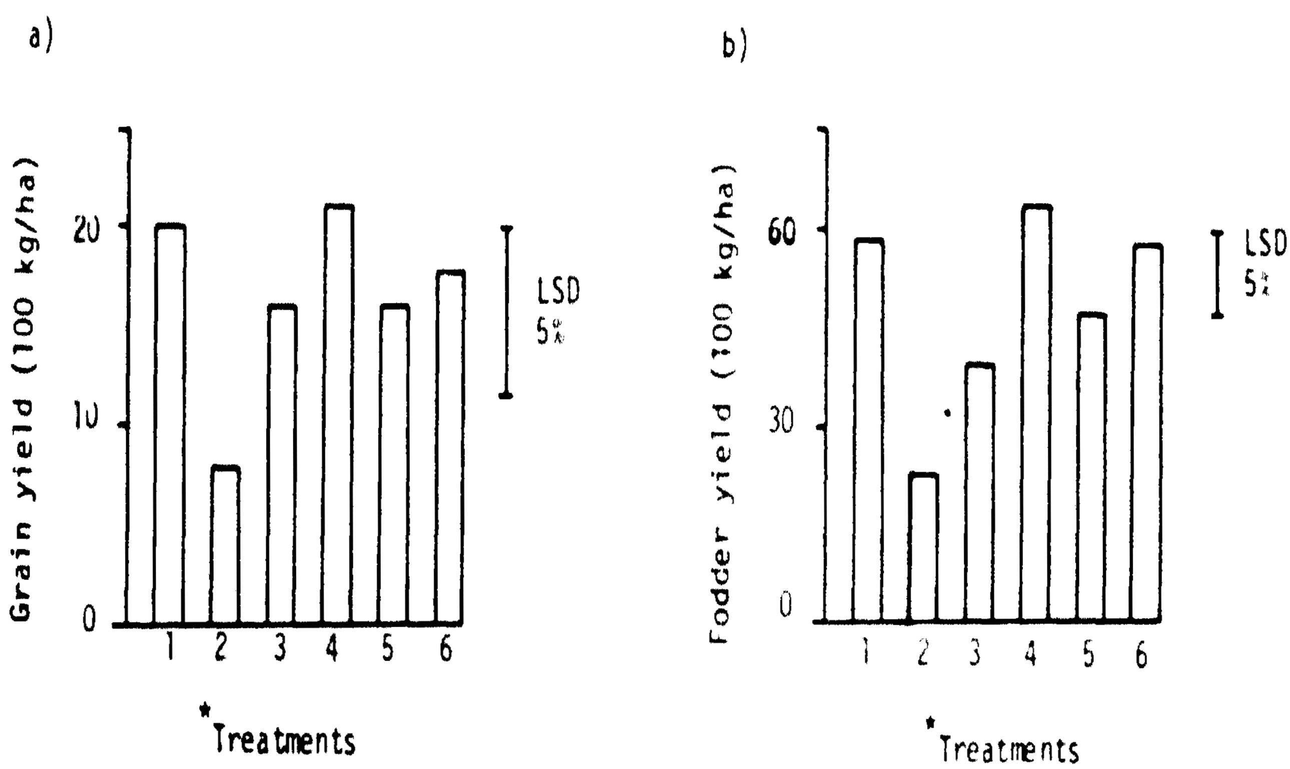

Fig. 22. THE EFFECT OF SEVERAL WEED CONTROL TREATMENTS ON SORGHUM GRAIN AND FODDER YIELD OF FARMER 4 AT KANZARA VILLAGE.

*
1. Weed free- low fert.
2. Weed check - low fert.
3. Farmer method - low fert.
4. Herbicide + farmer method - low fert,
5. Farmer method - high fert.
6. Herbicide + farmer method - high fert.

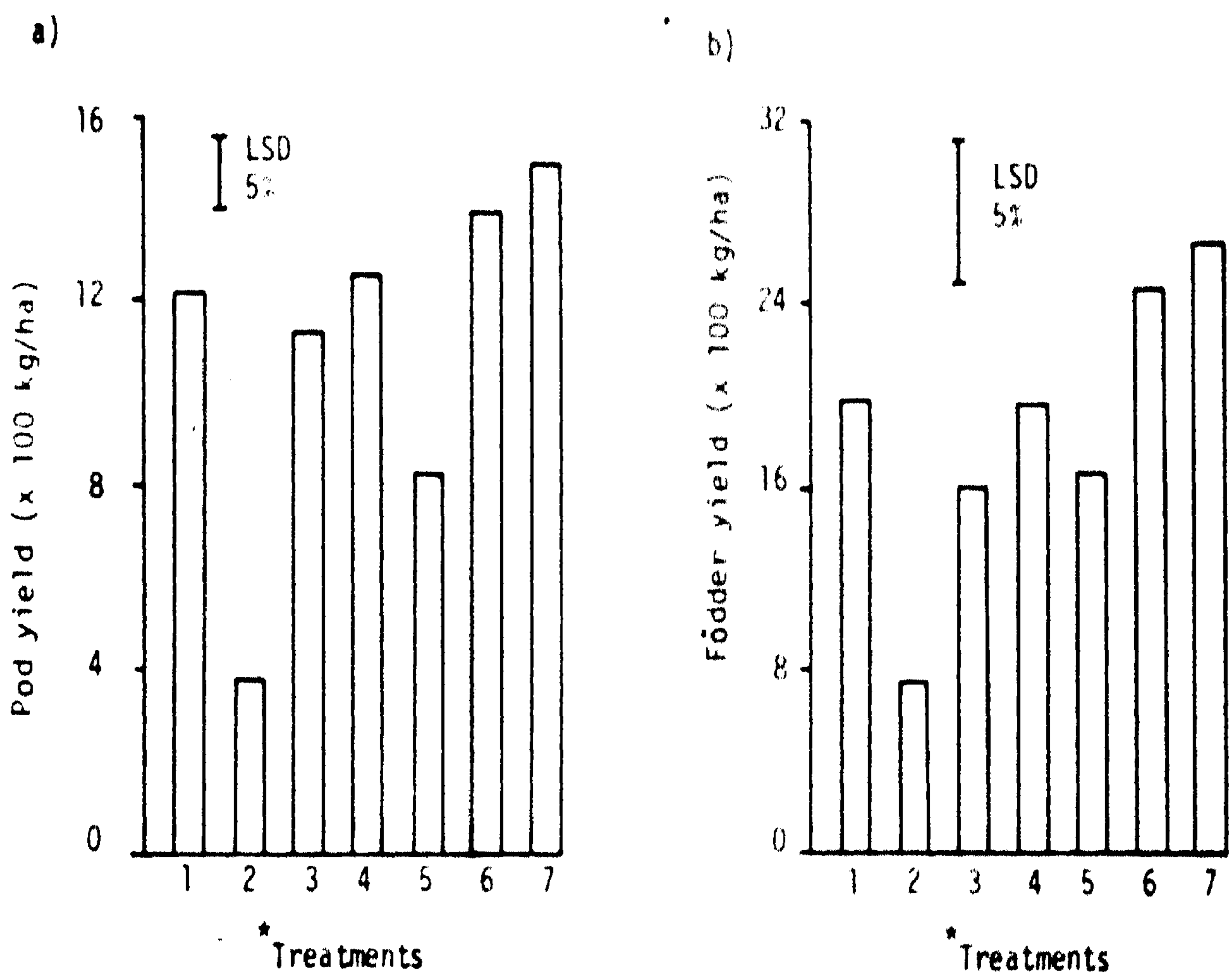

Fig. 23. THE EFFECT OF SEVERAL WEED CONTROL TREATMENTS ON GROUNDNUT a) POD YIELD AND b) FODDER YIELD OF FARMER 1 AT DOKUR VILLAGE.

*1. Weed free
2. Weed check
3. Herbicide - half rate
4. Herbicide - full rate
5. Herbicide + 1 hand weeding
6. Farmer method
7. Herbicide (full)+ farmer method

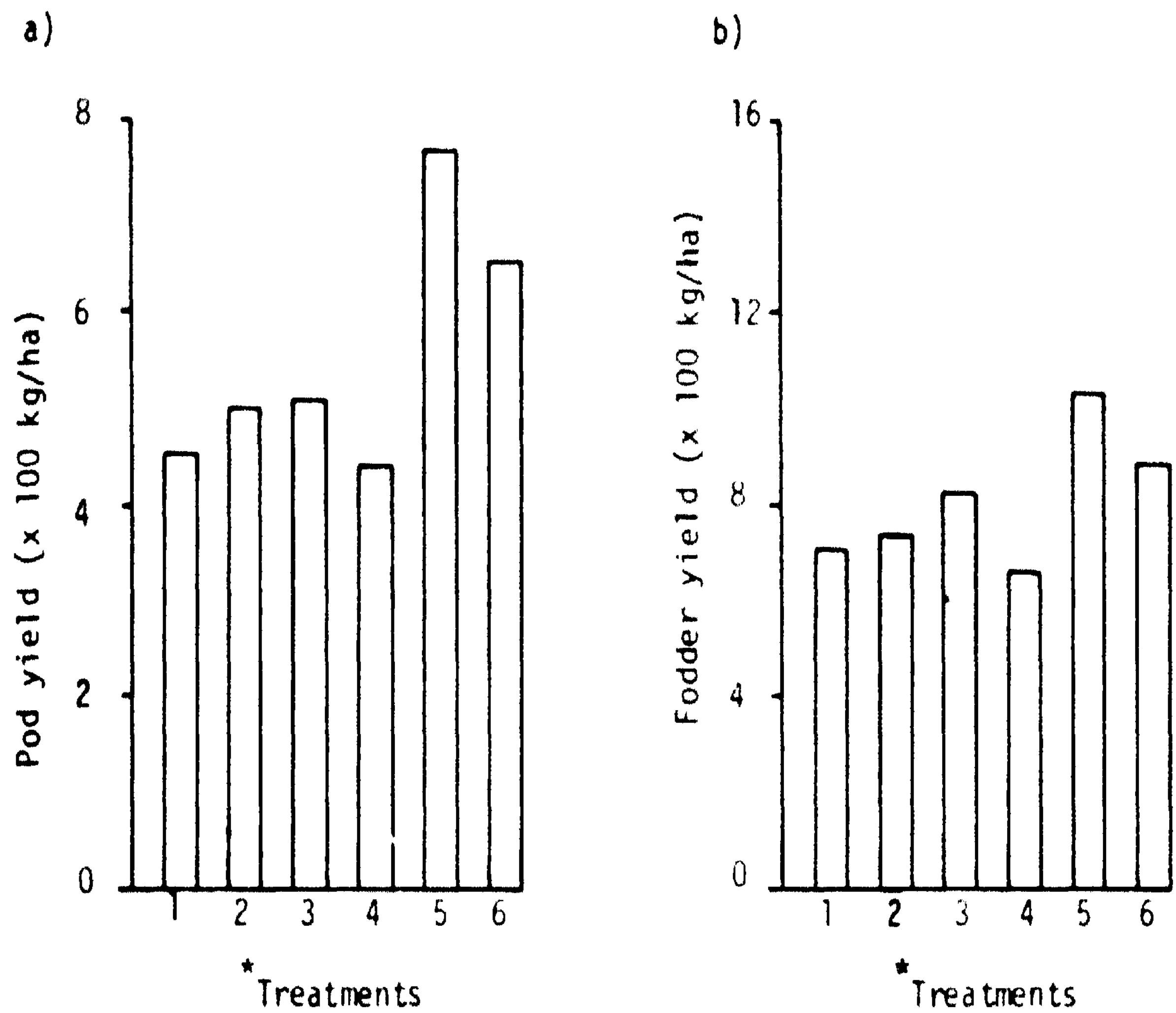

Fig. 24. THE EFFECT OF WEED CONTROL TREATMENTS ON GROUNDNUT a) POD YIELD AND b) FODDER YIELD OF FARMER 3 AT DOKUR VILLAGE.

*1. Weed free
2. Herbicide (½ rate)
3. Herbicide (full rate)
4. Herbicide + hand weeding
5. Farmer method
6. Farmer method + herbicide

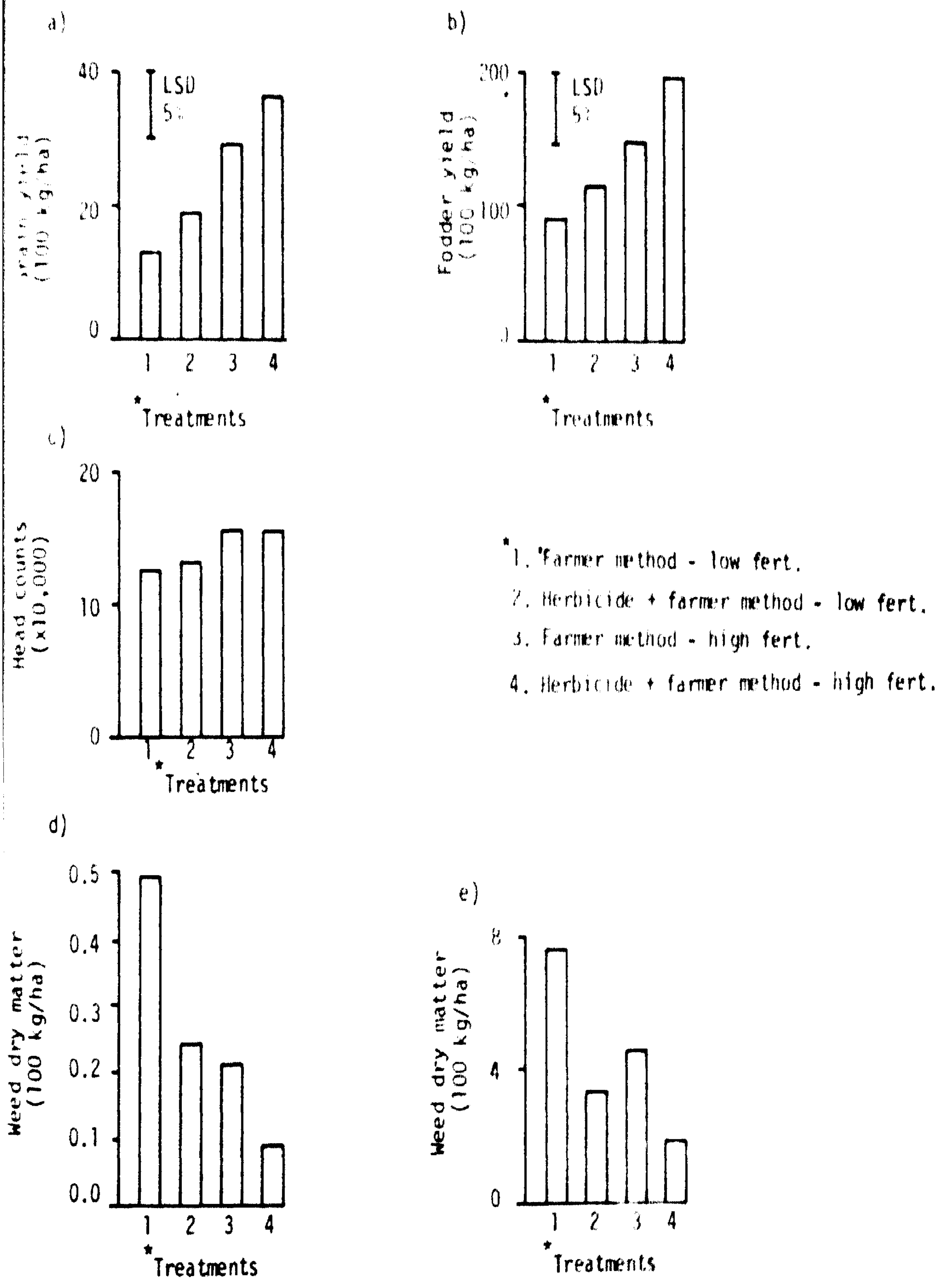

Fig. 25. THE EFFECT OF WEED CONTROL PRACTICES IN SORGHUM UNDER TWO FERTILIZER LEVELS, ON GRAIN YIELD, FODDER YIELD, HEAD COUNTS, AND WEED DRY MATTER, AT 65 DAYS AFTER SOWING AND HARVEST OF FARMER 1 AT POCHARAM VILLAGE.

7. Looking Ahead:

This is the fourth Annual Report of the Weed Management research in the Farming Systems Research Program of ICRISAT. Through these four years' experience it is increasingly felt that 'weed mangement' can provide a 'point of coordination' in the overall program since weed research transects all aspects of the systems like land and water management, tillage, cropping systems, crop variety and density, fertility, and also economics and therefore can serve as a practical 'vehicle' for systems research coordination. It is with this background, agronomic weed research is now being focussed mainly towards improving productivity of small farmers' farming systems on an 'year-round' basis. Therefore, cropping systems weed research will be given priority over sole crop weed research.

The primary emphasis will be on the evaluation of the principles of weed management which have wide applicability throughout the SAT. However, as no weed control method has ever been abondoned, at ICRISAT we will continue to develop alternate weed-management technologies.

We believe that the individual components of the integrated system should be examined in greater detail to develop effective measures of weed management, as illustrated in Fig. 1. We hope to intensity studies on agronomic manipulation of crop-weed balance. More emphasis will be placed on quantifying the affect of physical and biological factors... such as light, cultivar and density .. which effect crop-weed balance which can be easily manipulated. Eco-physiological studies to understand crop/crops-weed competition will be intensified.

The mechanical aspects of weed management are also being studied in greater depth under the animal-drawn-implement development program. We plan to study the relative merits/demerits of different implements in relation to weed spectrum, weed size, stimulation of weed seed germination, soil type and soil wetness. At ICRISAT Center we do not anticipate much expansion in herbicide related work except in rainy season cropping of deep Vertisols where herbicides are vital.

Weed monitoring studies will be expanded to determine how weed populations respond to crops, management techniques and systems of cropping and to quantify the downward/upward tendency of total weed populations under different management systems.

An aspect which will receive more emphasis is operational research, Improved, alternate weed management methods will be evaluated on a large scale with improved soil and water management and improved cropping systems. On-farm operational trials at different weed management systems under farmers' farming systems situations. This area of research is expected to be intensified along with the farming systems cooperative programs being initiated in the villages.

In collaboration with the plant breeders and physiologists we will continue to evaluate the performance different cultivars of ICRISAT crops under different weed management systems. As there is a wide gap existing between the performance of a new cultivar under high management situations of Research Center and that under 'real world' small farmer management levels - it is hoped to understand the major reasons through these type of trials. There will also be an increased emphasis on assisting national programs.

B. FORAGE AND FODDER EVALUATION

The objectives of the forage study project include:

1. Evaluation of promising forage legumes and grasses with regard to longevity, rapidity of regrowth at the beginning of the rainy season, soil erosion control, and ability to tolerate grazing pressure during the dry season.

2. Determination of the biological and economic fodder value of crop residues.

3. Evaluation of annual and long term shifts in the presence of grass, legume and other species in the "natural vegetation areas" on Alfisols and Vertisols at ICRISAT.

1.1 Evaluation of Grasses and Legumes in the Nurseries

Several grasses and legumes have been evaluated in the nurseries with regard to potentials for use in waterways, on tank bunds, etc. Field conditions well assumed; no weeding or supplemental irrigation took place. The grasses showed nitrogen deficiency symptoms in the late rainy season and 20 kg N/ha (Urea) was therefore applied. Twentysix collections of *Cenchrus ciliaris*, twentyfive of *Cenchrus setigerus*, sixtyone of *Panicum antidotale*, 20 other grass species and several legumes (*Clitoria ternatea Desmanthus virgatus, Atylosia scarabaeoides, Dolichos lablab, Siratro* and *Sesbania*) were studied; all these were planted a year earlier.

The establishment and first year regrowth of several grasses was excellent (Figs. 26-29). Severe competition of bermuda and *Dichanthium aristatum* (the most dominating grass on ICRISAT Vertisols) affected some plots; waterlogging during heavy rains was also observed. *Cenchrus ciliaris*: the green and dry fodder yield of the collection of *Cenchrus ciliaris* shows good performance of *C. ciliaris* 541, 393, Pusa giant and 214 (Fig. 26). Although the regrowth of *C. ciliaris* Molopo after the dry season was quite vigorous, total fodder yields were relatively small. Maximum green fodder production was obtained with *C. ciliaris* 541; the maximum dry fodder yield was recorded with *C. ciliaris*, Pusa giant. *C. ciliaris* 429 resulted in the lowest fodder yield.

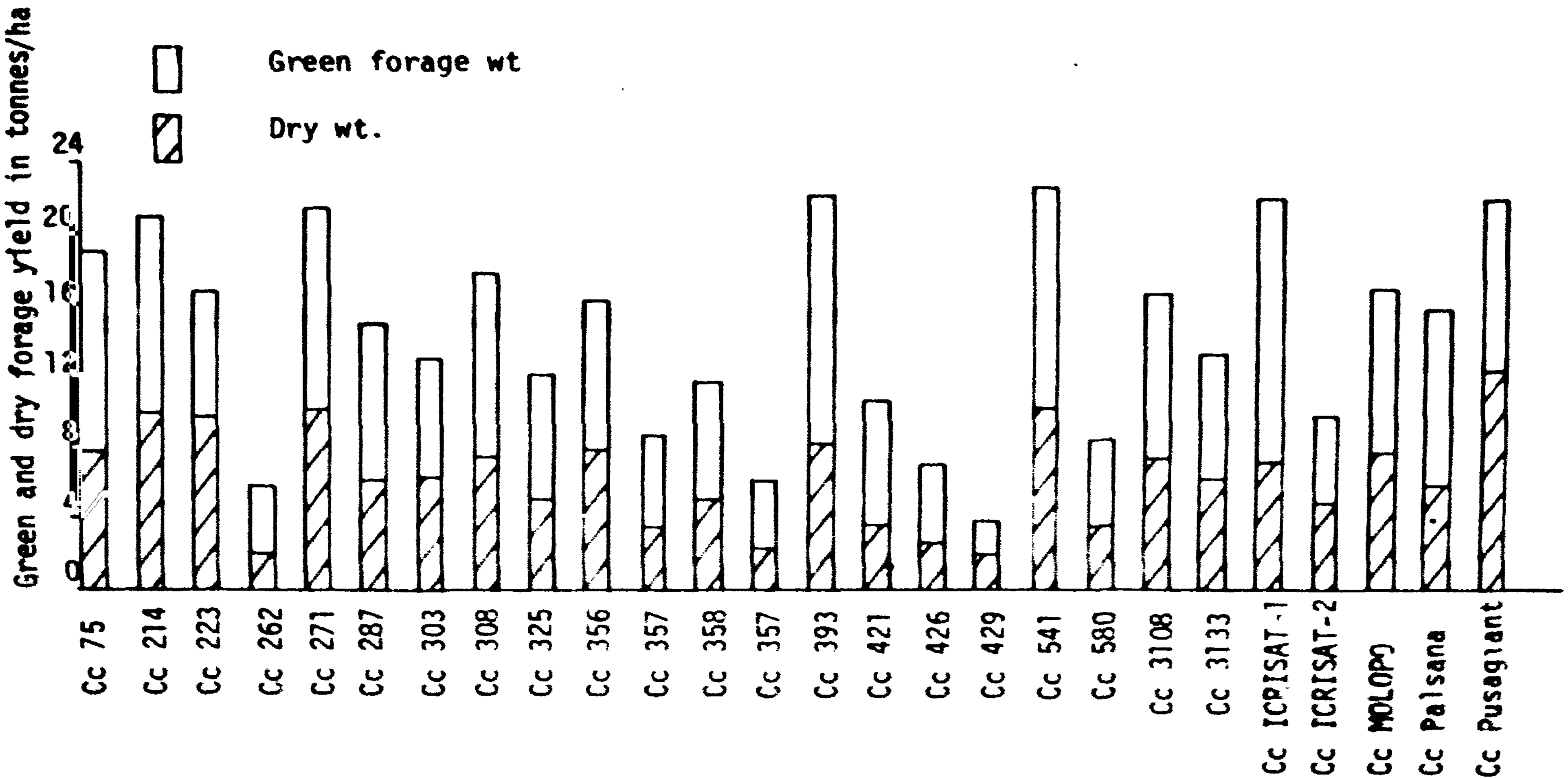

Fig. 26. Green and dry forage yields in 26 collections of *Cenchrus ciliaris*

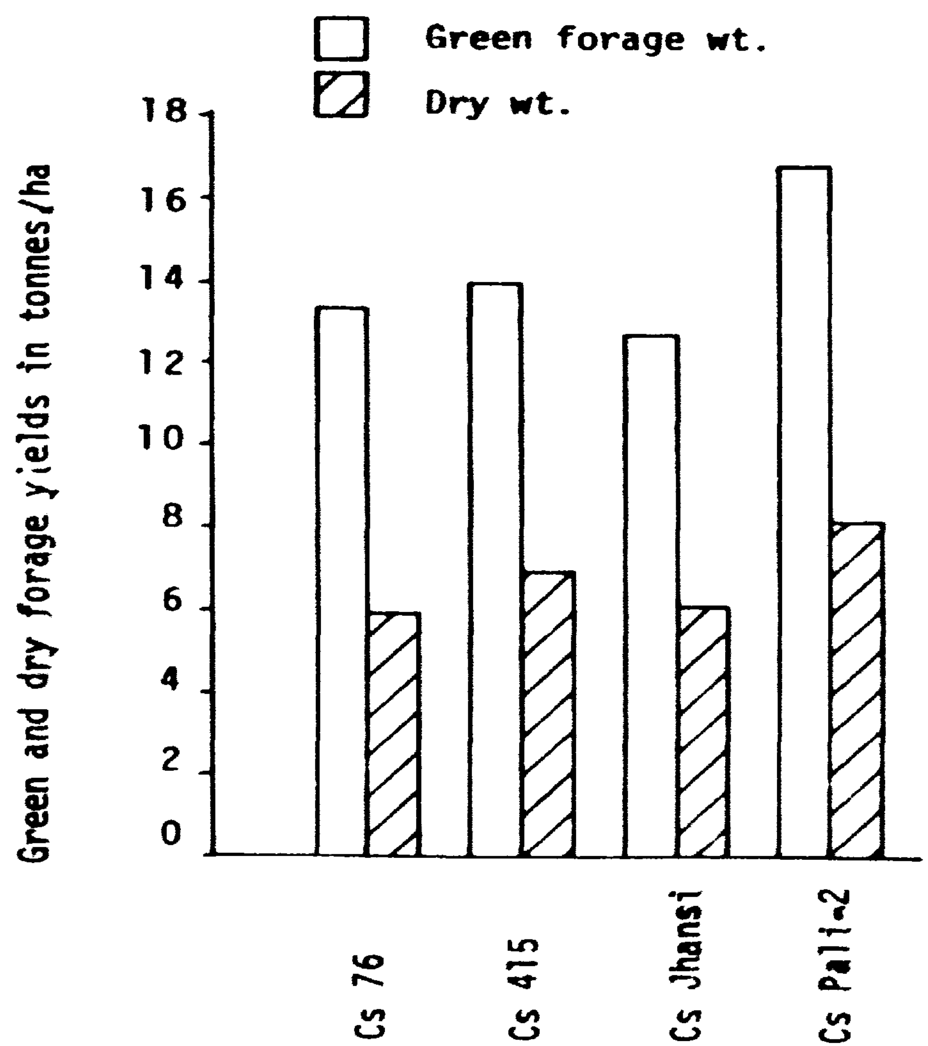

Fig. 27 Green and dry forage yields in 4 collections *Cenchrus setigerus*.

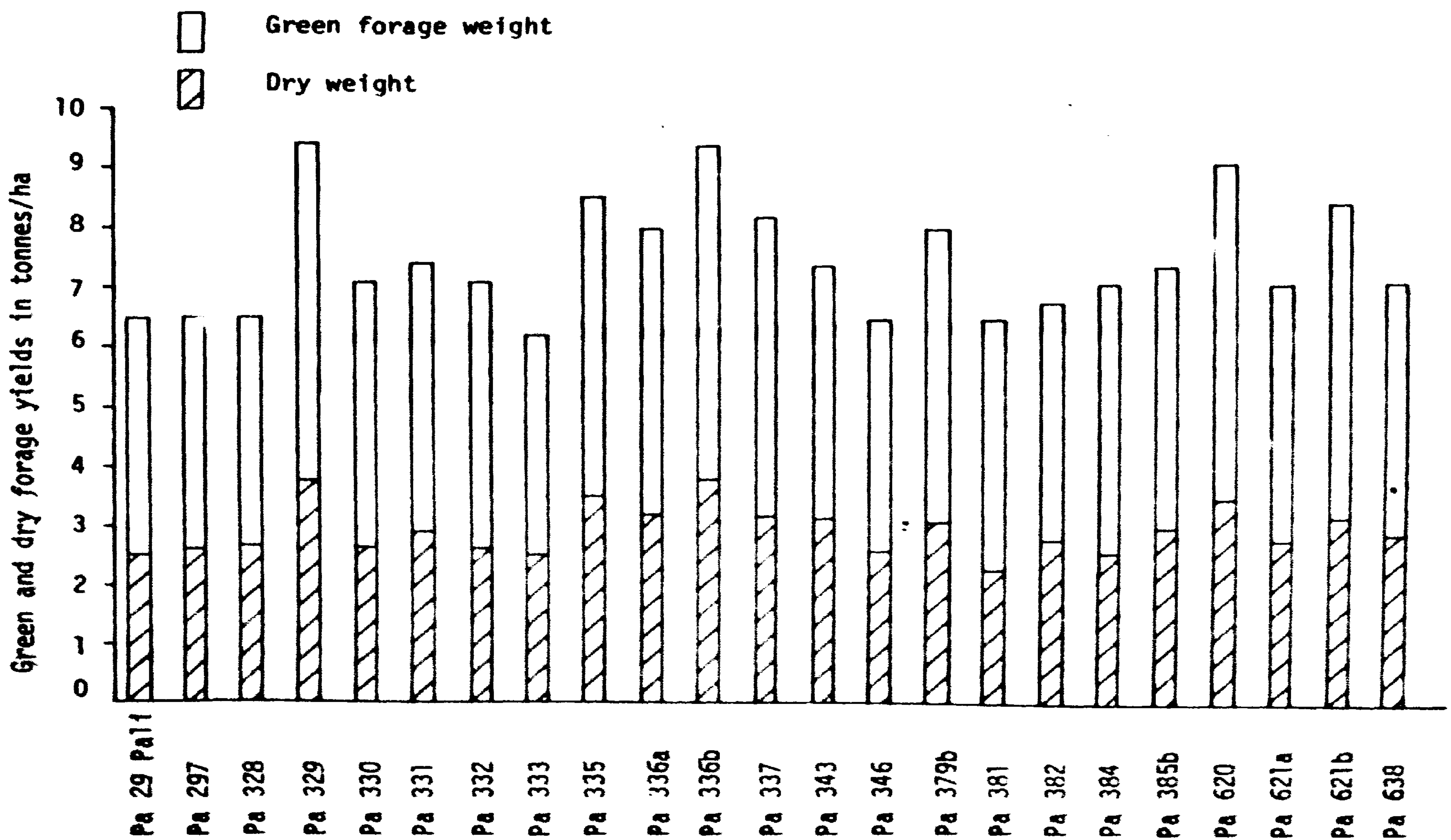

Fig. 28 Green and dry forage yields in 23 collections of *Panicum antidotale*.

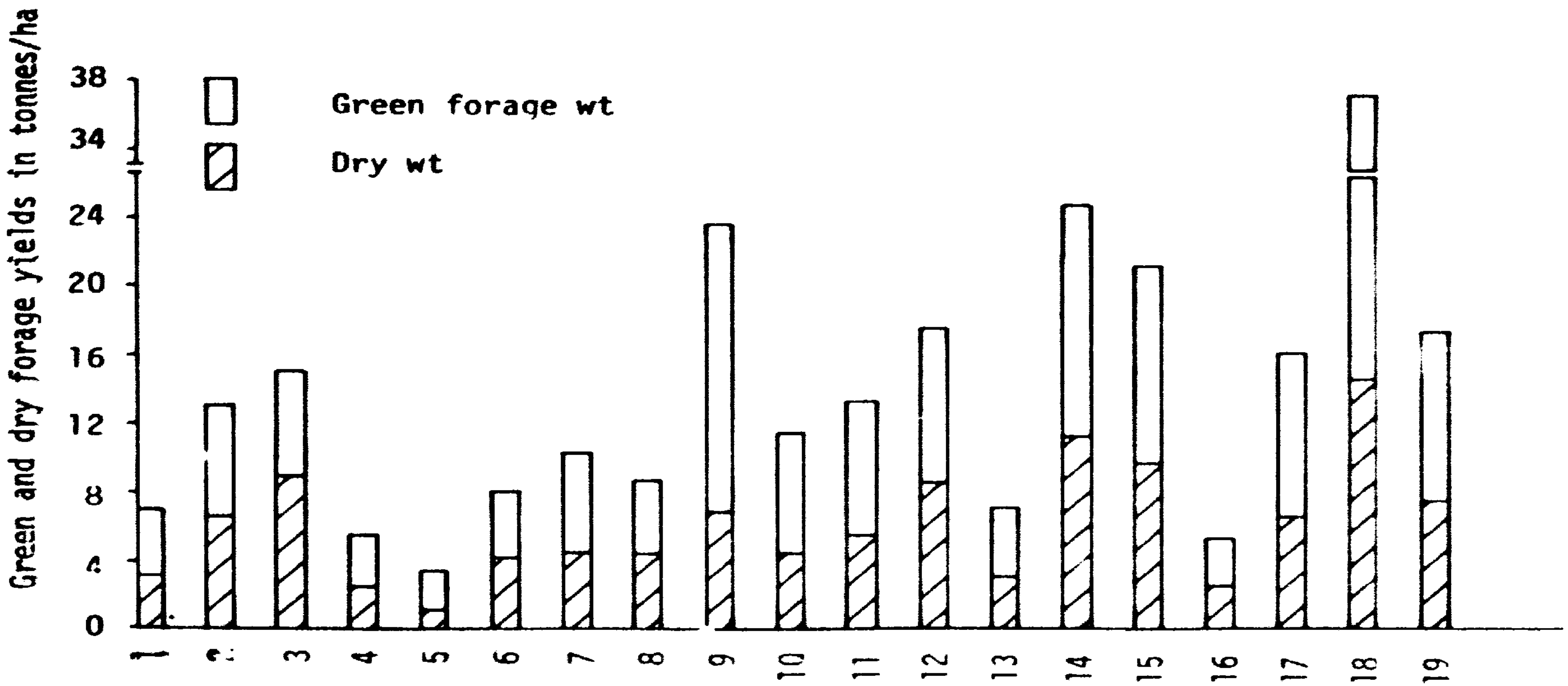

Fig.29 Green and dry forage yields of different grass species (No. 1-19, Actual names as listed below).

1. _Bothriochloa pertusa_
2. _Chloris gayana_
3. _Chrysopogon fulvus_
4. _Coix lachryma-jobi_
5. _Ischaemum rugosum_
6. _Pennisetum pedicellatum_
7. _Sorghum purpureosericeum_
8. _Sehima nervosum_
9. _Setaria spheelata_
10. Hybrid - napier x _P_ _squamulatum_
11. _Pennisetum squamulatum_
12. _P. aleopecures_
13. _P. villosum_
14. _P. massaicum_ 2n
15. _P. massaicum_ 4n
16. _P. rupelli_
17. Pusa giant Napier x _P. squamulatum_
18. Pusa giant Napier
19. Napier bajra

Cenchrus setigerus: In *Cenchrus setigerus*, out of 25 collections, establishment and regrowth was excellent in only four cases: *C. setigerus* 76, 415 and two others, one from Jhansi and one from Pali (Fig. 27). In the other 21 cases establishment and regrowth were unsatisfactory. Although it is generally known that this grass is not very suitable for the Vertisols, these four promising collections have been selected for further evaluation on Alfisols and Vertisols. *Panicum antidotale:* In *Panicum antidotale*, establishment and regrowth were satisfactory for about 1/3 of the collection, out of 61 collections, only 36 gave a green fodder yield above 5 tonns/ha (Fig. 28). The highest green and dry forage yield (9.4 t/ha and 3.8 t/ha respectively) was obtained with *P. antidotate* 329 and 336; the lowest yields (green forage 2 t/ha, dry forage 0.74 t/ha) were harvested with *P. antidotate* were partly due to strong competition of *Dichanthium* and also to heavy rain and water logging. This grass will be further evaluated on Alfisols.

Chloris gayana, Chrysopogon fulvus, Sorghum purpureo-sericeum, Setaria sphedata, Pennisetum squamulatum, P. aleopecures, P. massaicum and Pusa giant Napier all performed well in Vertisols (Fig. 29). Satisfactory establishment and regrowth was observed on Vertisols with *Clitoria ternatea* and Siratro, *Dolichos lablab* performed poorly due to heavy insect infestation. Excellent establishment and regrowth were observed in hedge lucerne (*Desmanthus virgatus*). Hedge lucerne, Siratro, *C. ternatea* were not cut of the normal dates in order to collect.

On Alfisols Siratro grew luxuriently; performance of *C. ternatea Glycine wightii* and *Centrosoma pubescerve* were also good. *Atylosia scarabaeoides* a naturally occuring legume on Alfisols performed very poorly on Vertisols. Similarly a dominant annual legume on Vertisols, *Indigofora glandulosa*, did not yield well on Alfisols, *Sesbania bispinosa* occurs on both Alfisols and Vertisols; it perpetuates by the production of large seed quantities.

Table 16: Green and dry fodder yields of grasses and legumes on Alfisols (Yields in t/ha)

Treatments[1]	Cut I		Cut II		Total	
	Green Fodder	Dry Fodder	Green Fodder	Dry Fodder	Green Fodder	Dry Fodder
U.m + Siratro Multicut + Grazing	14.8	5.9	14.2	5.8	29.1	11.7
U.m + Siratro Multicut	15.2	5.6	13.4	5.3	28.5	10.9
U.m + C.t Multicut + Grazing	11.3	4.2	10.8	3.9	22.1	8.1
U.m + C.t Multicut	11.2	3.7	10.0	3.6	21.2	7.3
C.c + Siratro Multicut + Grazine	13.9	7.6	15.0	6.1	28.9	13.7
C.c + Siratro Multicut	15.2	7.2	14.9	5.3	30.1	12.5
C.c + C.t Multicut + Grazing	15.1	5.2	12.4	4.4	27.5	9.6
C.c + C.t Multicut	13.5	5.1	12.2	4.7	25.7	9.8
C.g + Siratro Multicut + Grazing	16.3	6.1	15.7	5.8	31.9	11.9
C.g + Siratro Multicut	14.8	5.2	15.8	5.5	30.6	10.7
C.g + C.t Multicut + Grazing	11.3	4.0	13.8	5.1	25.1	9.1
C.g + C.t Multicut	12.7	4.6	15.0	5.3	27.7	9.9

[1] U.m - *Urochloa mosambicensis*
C.t - *Clitoria ternatea*
C.c - *Cenchrus ciliaris*
C.g - *Chloris gayana*

Table 17: Green and dry fodder yields of grasses and legumes on Vertisols (Yields in t/ha).

Treatments[1]	Cut I		Cut II		Total	
	Green Fodder	Dry Fodder	Green Fodder	Dry Fodder	Green Fodder	Dry Fodder
U.m + Siratro Multicut + Grazing	4.65	1.67	8.46	3.16	13.11	4.83
U.m + Siratro Multicut	6.25	2.31	7.50	2.78	13.75	5.09
U.m + C.t Multicut + Grazing	4.08	1.52	6.61	2.52	10.69	4.05
U.m + C.t Multicut + Grazing	3.75	1.48	7.75	2.83	11.5	4.31
C.c + Siratro Multicut + Grazing	5.37	2.12	8.98	3.55	14.35	5.67
C.c + Siratro Multicut	8.91	3.58	9.08	3.50	17.99	7.08
C.c + C.t Multicut + Grazing	7.41	3.00	9.41	3.70	16.82	6.70
C.c + C.t Multicut	6.31	2.51	9.00	3.45	15.31	5.96
C.g + Siratro Multicut + Grazing	7.06	2.80	13.25	5.26	20.31	8.06
C.g + Siratro Multicut	7.93	3.20	12.93	5.15	20.86	8.35
C.g + C.t Multicut + Grazing	6.77	2.35	12.80	5.05	19.57	7.40
C.g + C.t Multicut	5.59	2.20	10.77	4.01	16.36	6.21

[1] U.m - *Urochloa mosambicensis*
C.c - *Cenchrus ciliaris*
C.g - *Chloris gayana*
C.t - *Clitoria ternatea*

1.2 Grass Legume Mixtures:

A grass-legume mixture trial including three grasses and two legumes was planted in 1977 on Alfisols and in April 1978 on Vertisols. The trial aims to study the comparativity forage production and longevity of six grass legume mixtures cut repeatedly with and without grazing during the dry season. No supplemental water was given. In this year (July 1978 - June 1979) two harvest cuts were applied; in addition, grazing by bullocks was conducted in the trial on Alfisols for the treatments with multicut harvests and grazing management. The data are presented in Tables 16 and 17.

1.2.1 Alfisols:

The highest green fodder production (31.9 t/ha) was obtained with the *C. gayana* and Siratro mixture *C. ciliaris* with Siratro yielded the greatest dry matter production (13.7 t/ha). The performance of all three grasses (i.e. *Cenchrus ciliaris, Chloris gayana* and *Urochloa mosambicensis*) grown with Siratro was better than the association with *Clitoria ternatea*. In the Siratro based combinations, fodder production was greater when they were grazed in the dry season. In the *C. ternatea* based combinations the treatment with dry season grazing resulted in erratic production effects. With grazing yields slightly increased with *U. mosambicensis*, however they decreased with *C. ciliaris* and *S. gayana*. The forage yields of successive cuttings (without grazing) in general decreased, sometimes there was little difference. In *C. gayana* *C. ternatea* however, an increasing trend was observed in the forage yields of successive cuttings in grazing as well as in non-grazing treatments.

1.2.2 Vertisols:

On Vertisols, the highest green and dry fodder production was obtained with the *C. gayana* Siratro mixture. Performance of *C. ciliaris* was poor when grown on flat land. It is interesting to note that the growth of *C. ciliaris* was better in a near by nursery where it was grown on broadbeds. The performance of *U. mosambicensis* was poor on Vertisols. On the Vertisols, grazing was applied in May 1979 and its impact will be studied in the next season.

1.3 Natural Vegetation Studies

1.3.1 Species Present in Alfisols:

The vegetative cover on the Alfisols is predominated by *Heteropogon contortus*, *Bothriochloa pertus* and other species. The predominant families represented are Fabaceae and Poaceae. In the vegetation strata (except for local shrubs) *H. contortus* is at the highest level and other species occupy the lower levels. *B. pertusa* forms a thick carpet about 1 5 feet high. At the outset of the rains the perennial spceis sprout from root stocks, annuals regrow from seeds. The density of seedlings is often high and competition for space, light and nutrients is severe. The vegetative period extended upto October in many species (it was a relatively wet year). In some species more than one flush of flowering and seed formation were observed.

The following species have been recorded within the fenced areas on Alfisols:

Acanthaceae

Lepidagathis cristata wild

Amaranthaceae

Achyranthus aspera L.

Aervalanata Juss

Celosia argentea L.

Gomphrena celosoides Mart

Apocynaceae

Catharanthus pusillus (Murr) Don

Asclepediaceae

Hemidesmus indicus R.Br.

Asteraceae

Acanthospermum hispidum Dc.

Ageratam conyzoides L.

Echinops echinatus Dc.

Pulicaria wightiana (Dc) cl.

Tridax procumbens L.

Vernonia cinerea (L) Less.

Caryophyllaceae

Polycarpea corymbosa (Linn) Lamk.

Celastraceae

Gymnosporia montana (Roth) Benth.

Maytinus emarginata (Wild) Ding Hov.

Convolvulaceae

Evolvulus alsinoides L.

Cyperaceae

Cyperus rotundus L.

Cyperus sps.

Euphorbiaceae

Phyllanthus madraspatensis Linn.

Fabaceae

Alysicarpus rugosus (Willd) Dc.

Atylosia scarabaeoides Benth.

Butea monosperma (Lamk) Taud.

Cassia auriculata L.

C. tora L.

Crotalaria retusa L.

Indigofera linifolia (L.f)

I. ennaphylla L.

Tephrosia hirta Ham.

Zornia diphylla. Acut.

Lamiaceae

Leucas aspera (Willd) spr.

Ocimum basilicum L.

Liliaceae

Gloriosa superba L.

Malvaceae

Sida acuta Burm. F.

Meliaceae

Azadirachata indica A. Juss.

Poaceae

Alloteropsis cimicina (L) Staff.

Aristida adscensionis L.

A. hirtigluma steud ex Trin. et Rupr

A. hirtax L.f

Bothriochloa pertusa (L) A. Camus

Digitaria ciliaris (Retz) Koeler

Heteropogon contortus (L) Beaur

Perotis indica (L) Kuntze

Rhamnaceae

Zizyphus sp.

Rubiaceae

Borreria articularis (L.f) will

Oldenlendia (Heyne ex Roth) Dc

O. Corymbosa L.

Scrophulariaceae

Striga lutea Lour

Solonaceae

Withania Somnifera (L) Dunae

Tiliaceae

Grewia hirsuta Vahl

Triumfetta rotundifolia Lam.

Verbinaceae

Lantana camara L.

Vitex negundo L.

1.3.2 Species present on Vertisols:

The natural vegetation on Vertisols is primarily a *Sehima* - *Dichanthium* cover. *Iseilema laxum* is a another important grass on Vertisols. The green and dry fodder of these two grasses is valued highly becuase of good palatability. Another notable grass on Vertisols is the tall, robust and perennial *Ischaemum pilosum*. The infrequent reoccurrence of *Heteropogon contortus* on the fenced Vertisol is interesting. *Acacia arabica* forms the uppermost stratum, *Dichanthium aristatum* is found in the middle and other annual species occupy the basal strata. Some legumes like *Atysicarpus longifolius* and *Indigofera trita* grow taller than the grass cover. Acacia is found scattered everywhere often in association with other shrubs, (or small trees) like *Cassia fistula*. *C. auriculata, Zizyphus* sp. *Butea monosperma* and *Azadirachta indica*. The growth of *Prosopis juliflora* bushes is much faster than *Acacia*. The survey of vegetation reveals that number of species is greater in Vertisols compared to Alfisols. Following species have been recorded from fenced area in Vertisols.

Acanthaceae

Hygrophila auriculata (K. schum) Heine
Justicia simplex L.
Lepidagathis cristata Wild.

Amaranthaceae

Achyranthus aspera L.
Aerva lanata (L) Juss
Celosia argentea L.

Asclepediaceae

Calotropis gigantea (L) Dryland
Calotropis procesa (Ait) R. Br.

Asclepediaceae

Acanthospermum hispidum Dc.
Ageratum conyzoides L.
Flaveria australasica H.K.
Lagascea mollis Cav
Xanthium strumarium L.

Boraginaceae

Coldenia procumbens L.
Trichodesma zeylenicum (Burm) R.Br

Commelinaceae

Caesulia axillaris Roxb

Convolvulaceae

Convolvulus arvensis L.
Evolvulus alsinvides L.
Ipomoea sps.
Merremia emerginata (Bunn) Hall f.

Cucurbitaceae

Cucumis sp.

Cyperaceae

Cyperus rotundus L.
Cyperus sps.

Euphorbiaceae

A. Calypha indica Linn.

Phyllanthus madraspatensis L.

Tragia hispida Willd

Fabaceae

Acacia arabica auct

Aeschynomene indica L.

Alysicarpus buplerifolius (L) D.c

A. longifolius W & A

A. monilifer D.c

A. rugosus (Willd) D.c

Atylosia scarabaeoides Benth

Cassia auriculata L.

C. tora L.

Desmodium diffusum D.c

Indigofera cordifolia Heyne ex Roth

I. glandulosa L.

I. linifolia (L.f) Retz

I. trita L.

Mimosa hamata Willd.

Phaseolus trilobus L. Verdcourt.

Prosopis juliflora (Swartz) D.c

Sesbania bispinosa (Jacq) pers.

Lamiaceae

Lavandula burmani Benth.

Leucas aspera (Willd) Spr.

Lauraceae

Cassytha filiformis L.

Liliaceae

Curculigo orchiodes Gaertn

Malvaceae

Abelmoschus esculentus moench

Abutilon indicum (L) Sweet

Hibiscus panduraeformis Burm

Pavonia zeylenica can.

Sida acuta Burm.

Menispermaceae

Cocculus hirsutus (L) Diels

Pedaliaceae

Martynia annua L.

Poaceae

Brachiaria eruciformis (Sm) Griseb

Chloris barbata Sw.

C. virgata Sw.

Cymbopogon martinii (Roxb) wats

Cymbopogon sp.

Dichanthium annulatum (Forst) Stapf

Dichanthium aristatum av (poir) Hubb

Eleusive indica (L) Gaertn

Imperata cylindrica (L) Beauv.

Ischaemum pilosum Hack.

Panicum repens Linn.

Themeda quadrivalvis (L) Kuntze.

1.3.3 Fertilization and Management of Natural Vegetation:

An experiment to study the effect of phosphorus application and management systems upon forage production, botanical composition and longevity of the native grasses and other species, was continued from 1977. The effects of different levels of phosphorus (0 P and 20 P/ha) were studied under uncut and multicut management.

Seedlings of several annual species like *Indigotera glomdulosa I linifolia. I cordifolia Alysicarpus sps* and *Desinadium sps* and others appeared with the first showers; the perennials also resumed growth. By the end of June the whole plot area was fully covered. Observations on the density and frequency of the species presen have been taken. These data will be studied for two more years to determine effects on botanical composition. The height of the grass cover and total yearly forage yields are presented in Table 17. Height of grass cover and forage production was greatest on Vertisols. The management system appears to have a specific effect on the composition of the vegetation. In plots under uncut treatment the perennial species are dominating; in those under multicut management the annual species predominate. These annual species which generally cover the ground strata are mostly ephemerals.

1.3.4 Vegetation Study on Line Transect:

In the natural vegetation areas in Alfisols and Vertisols, permanent bench marks have been located at three points in each area. All these species occuring on the "line transects" between benchmarks have been recorded twice during the year: (I) in the peak growing season, and (II) in the dry summer season. Observations reveal that on Vertisols there is as yet little change in the composition of the vegetation; however, on Alfisols *Heteropogon contortus* and *Bothriochloa pertura* appear to become more frequent. All other species appear to be suppressed by these two grasses; a long-term study may reveal interesting results.

C. STEPS TOWARDS IMPROVED TECHNOLOGY

Improved crop production technology involves many practices which may be used in a large number of combinations. These have been grouped into four "steps" viz., crop variety, fertilization, soil and crop management and supplemental water, which have been studied in several combinations.

In 1978 a sorghum/pigeonpea intercrop on the Alfisol and a maize/pigeonpea intercrop on the Vertisol were studied using 10 different combination of the four improved technologies. The crops were sown at the onset of the rainy season. Germination and seedling growth were excellent in all treatments. Although the crops suffered somewhat from excessive rain and cloudy weather during July and August growth and grain formation of the improved varieties were satisfactory; however grain formation was poor on the local sorghum. The results are summarizea in Table 18.

On the Alfisol the gross returns for the sorghum/pigeonpea intercrop with improved varieties increased 750 Rs/ha for improved fertilization and 1160 Rs/ha for improved management applied singly. When used in combination the increased return was 2510 Rs/ha giving a synergistic effect of 600 Rs/ha. When traditional varieties were used the increases were -360 Rs/ha for fertilization, 650 Rs/ha for management, 770 Rs/ha for the combination, with a synergestic increase of 480 Rs/ha. Use of improved varieties alone increased returns 500 Rs/ha but when combined with improved fertility and better soil and crop management the increase was 2190 Rs/ha. There was no response to irrigation on either the Alfisol or Vertisols reflecting the high 1978 rainfall.

The values of the maize/pigeonpea intercrops on the Vertisols increased from 2290 to 4620 Rs/ha when traditional varieties and practices were replaced by a full set of improved technologies. Increases for varieties were 290 and 320 Rs/ha when grown with and without improved fertilization and management. Improved fertilization used alone increased returns of traditional varieties 720 Rs/ha and improved varieties 1560 Rs/ha. Improved management alone increased returns 630 and 890 Rs/ha on traditional and improved varieties respectively. The synergistic effects of the combined use of improved fertilization and improved management were 690 and 290 Rs/ha on traditional and improved varieties respectively.

These results illustrate the interdependence among the various factors of production and have gain emphasized the complementarity and synergism of the joint use of a set of improved technologies.

Table 18: Yield and monetary returns for two intercrop systems under different combinations of improved production practices.

Treatments*					Maize/Pigeonpea				Sorghum/Pigeonpea			
					Maize		P.pea	Return**	Sorghum		P.pea	Return
					Grain	Fodder	Grain		Grain	Fodder	Grain	
	V	F	M	I	Kg/ha	Kg/ha	Kg/ha	Rs/ha	Kg/ha	Kg/ha	Kg/ha	Rs/ha
1.	-	-	-	-	970	580	500	2290	300	4170	700	1960
2.	-	-	+	-	1210	600	710	2920	440	3550	920	2610
3	-	+	-	-	1780	1950	530	3020	780	5580	420	1600
4.	-	+	+	-	2460	1540	800	4340	1000	6870	810	2730
5	+	-	-	-	580	430	570	1980	1150	2360	640	2400
6	+	-	+	-	960	480	780	2860	1560	2220	990	3570
7	+	+	-	-	1830	540	720	3540	2970	4250	430	3150
8.	+	+	+	-	2710	1380	820	4620	3420	3830	1010	4820
9	-	+	+	+	1990	1650	830	3970	970	7130	910	2950
10.	+	+	+	+	2600	1260	990	4950	3290	3860	1040	4900

*V - Variety; F - Fertilization; M - Soil crop management; I - Irrigation; a - Indication. See 1977 Annual Report for details. Traditional and a + indicates improved practice.

**Sorghum 70 Rs/q; Maize 95 Rs/q; Pigeonpea 250 Rs/q; Fodder No value

D. VILLAGE LEVEL STUDIES - PHASE II

On-farm experiments were initiated in three villages (Shirapur and Kanzara in Maharashtra and Aurupalle in Andhra Pradesh) to obtain preliminary information on suitable cropping systems and appropriate land management methods, and in preparation for a follow-up of studies of traditional cultivation practices and resource availabilities in SAT India (See section XX). An area varying in size between 2.5 and 4 ha belonging to a single farmer was selected in each village. This area was planted to aseries of thrice replicated trials in which the major purpose was to test the effects of improved land management using the bullock-drawn tropiculteur on dryland cropping systems which are typical of, or could potentially be important to, the farmers of an area. The planting methods compared were: sowing on graded broadbeds or on flat cultivated land using the wheeled tool carrier and sowing on flat with existing equipment. The cropping systems were: a sorghum/pigeonpea intercrop at Aurepalle and Kanzara, sequential crops of mungbean - sorghum and maize - chickpea at Shirapur and Akola respectively, rainy season fallow - sorghum at Shirapur, sorghum - ratoon sorghum at Akola, and sole crops of castor and millet at Aurepalle.

The diversity of the agroclimatic regions represented by these villages and the erratic nature of the precipitation is clearly illustrated by the rainfall patterns of 1977 and 1978 (Fig. 30). The total annual rainfall in Shirapur was 411 and 962 mm respectively in 1977 and 1978; in Kanzara precipitation in these years amounted to 1050 and 1046 mm and in Aurepalle to 522 and 1010 mm. Contrary to the situation in 1977, rainfall at all locations appeared reasonably well distributed and in excess of the long term averages.

Primary tillage and land preparation were completed just before the growing season. The experimental treatments were designed to determine the quantitative effects of the implementation of several phases of improved technology in relation to the yields obtained in the existing systems of farming. It appeared that weed control was a more serious problem in the "improved" technology treatments compared to "traditional"

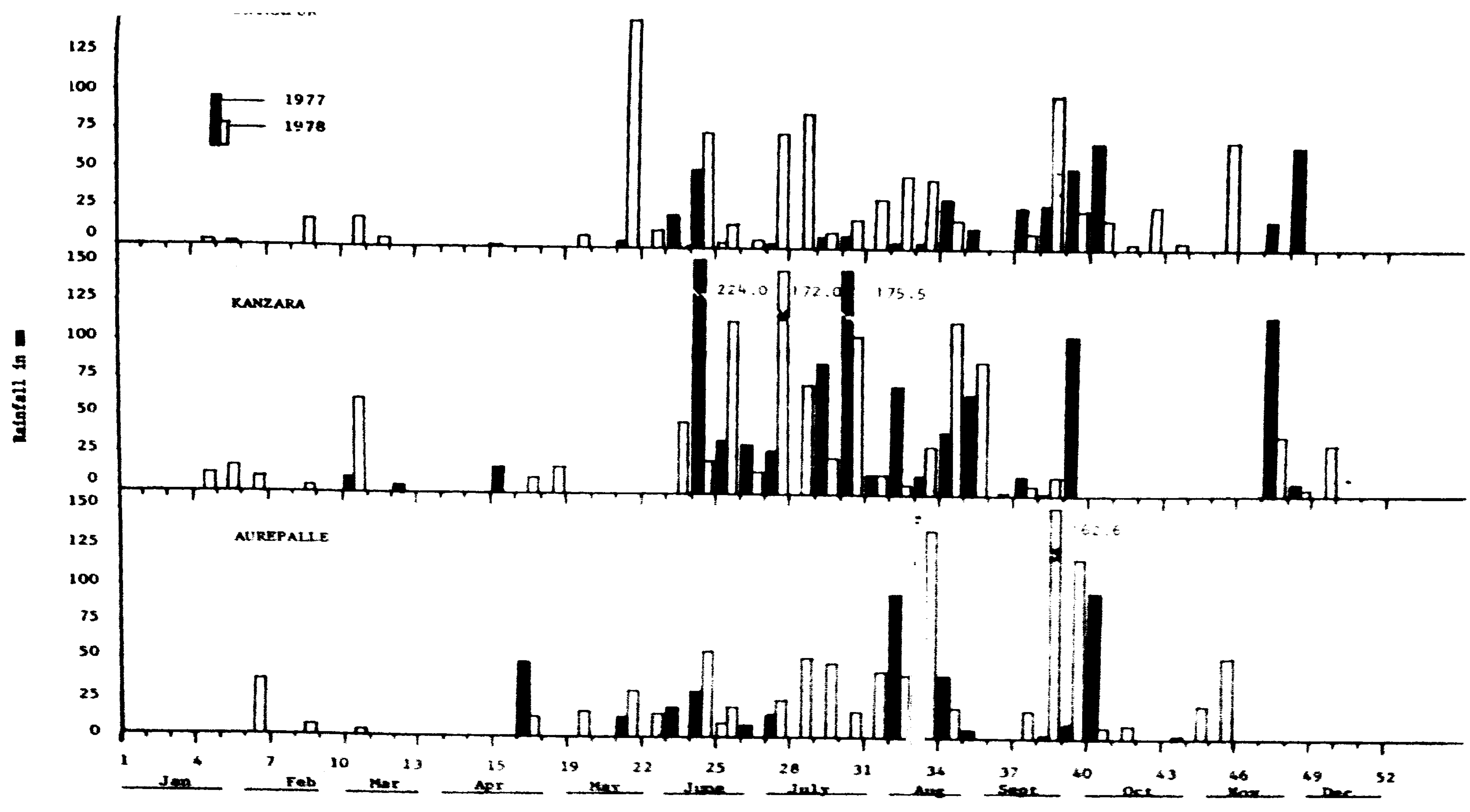

Fig. 30 Rainfall distribution in Shirapur, Kanzara, and Aurepalle in 1977-78

systems. Although these problems may have been exaggerated because of unusually wet conditions, it must be recognised that the present practice is to cultivate and plant after the initial rains. Farmers use the blade harrow on "bukher" on moist soil; this operation eliminates the first flush of weeds. In the improved dry sowing on Vertisols and even on Alfisols, there is less time allowed for weed control because of the overriding importance of early planting. More or less continuous rains after planting. More or less continuous rains after planting (as occurred in Kanzara) further aggravated the weed problem because of difficulties in manual and mechanical weeding. The use of chemical fertilizers also encourages weed growth. The controlled use of herbicides may therefore have to be further investigated.

The grain yields obtained and the gross monetary values of alternative cropping systems have been summarized in Tables 19 and 20 respectively. It is striking how intimately improved crop management technology is apparently related to precision equipment (e.g. the pigeonpea intercrop in sorghum at Aurepalle yielded about 1.3 q/ha with existing implements and almost 5 q/ha with the tropiculteur; the respective yields for sorghum after mungbean in Shirapur were about 6.8 and 13.7 q/ha; for sorghum intercropped in pigeonpea in Kanzara, the respective yields were about 11 and 16 q/ha. Crop yields with the graded broadbed cultivation system exceeded those of the planted systems in case of castor in Aurepalle; of pigeonpea sorghum after fallow, and mungbean in Shirapur; and of sorghum intercropped in pigeonpea and sole rainy season sorghum in Kanzara. Yields on flat planted systems exceeded those on the, graded broadbed system in other cases. Improved farming systems greatly outyielded the existing systems at all locations in all cropping systems except for postrainy season sorghum in Shirapur.

The number of treatments during this first year of on-farm experimentation was large, the additional requirement of three replicates resulted in small individual plots. Thus, much time - and land - was lost in turning animals and equipment. This aspect was emphasized by farmers and decreased their attention for the yield performance of successful treatments. Fewer treatments of reasonable size would have made greater impact.

Table 19: Grain yields (q/ha) of alternative treatments in on-farm experiments 1978-79

Cropping Systems/Land Management		Shirapur	Kanzara		Aurepalle	
Sorghum/pigeonpea on broadbeds with T.C.[1/]	2/	17.3	15.8	3/	17.0	4.8
Sorghum/pigeonpea flat planted with T.C.	2/	16.3	14.0	3/	17.3	3.6
Sorghum/pigeonpea flat planted traditional implements	2/	13.2	11.2	3/	13.1	1.6
Mungbean followed by sorghum (Shirapur); maize (Kanzara); and castor (Aurepalle) - on broadbeds with T.C.	4,8	12.4	10.9		6.6	
Mungbean followed by sorghum (Shirapur); maize (Kanzara); and castor (Aurepalle) - flat planted with T.C.	4,1	13.7	12.7		5.6	
Mungbean followed by sorghum (Shirapur); maize (Kanzara); and castor (Aurupalle) - flat planted with traditional implements	2,8	6.8	8.5		3.6	
Rainy season fallow - sorghum (Shirapur); sole sorghum (Kanzara); and pearl millet - pigeonpea (Aurepalle) - on broadbeds with T.C.		14.5	11.5		5.9	2.4
Rainy season fallow - sorghum (Shirapur) sole sorghum (Kanzara); and pearl millet - pigeonpea (Aurepalle) - flat planted with traditional implements		10.9	9.3		2.3	.6
"Traditional" sorghum after fallow (Shirapur); rainy season sorghum (Kanzara); and castor (Aurepalle)		8.2	1.6			1.3

1/ T.C. stands for the tropiculteur.

2/ The rainy season sorghum was wiped out by shootfly.

3/ The pigeonpea crop was destroyed by grazing cattle.

APPENDIX - I

A LIST OF MAJOR CROP WEEDS AT ICRISAT

ACANTHACEAE:

- *Justicia simplex* D. Don

AMARANTHACEAE:.

- *Achyranthes aspera* L.
- *Aerva lanata* (L.) Juss.
- *Amaranthus spinosus* L.
- *Amaranthus viridis* L.
- *Celosi cargentea* L.
- *Digera arvensis* L.

APOCYANCEAE:

- *Catharanthus pusillus* (Murr.) G. Don

ASTERACEAE: (COMPOSITAE)

- *Ageratum conyzoides* L.
- *Caesulia axillaris* 'Roxb.
- *Eclipta alba* (L.) Hassk.
- *Goniocaulon glabrum* Cass.
- *Gnahalium polycaulon* Persoon.
- *Lagascea mollis* Cav.
- *Launaea acaulis* (Roxb.) Kerr.
- *Oligochaeta ramosa* Ramosa
- *Sonchus oleraceus* L.
- *Sphaeranthus indicus* L.
- *Tridax procumbens* L.
- *Vernonia cinerea* (L.) Less.
- *Vicoa indica* (L.) DC.
- *Xanthium strumarium* L.

BORAGINACEAE:

- *Trichodesma indicum* (L.) Lehmann
- *Trichodesma zeylanicum* (Burm.) R. Br.

CAPPARIDACEAE:

- *Cleome monophylla* L.
- *Gynandropsis pentaphylla* DC.
- *Cleome viscosa* L.

CARYOPHYLLACEAE:

Polycarpaea corymbosa (L.) Lamk.

COMMELLINACEAE:

Commelina benghalensis L.

Amischophacelus axillaris (L.)

CONVOLVULACEAE:

Convolvulus arvensis L.

Evolvulus alsinoides (L.)

Merremia emarginata (Burm.) Hall. F.

CYPERACEAE:

Cyperus cuspidatus Kunth

Cyperus difformis L.

Cyperus iria L.

Cyperus rotundus L.

EUPHORBIACEAE:

Acalypha indica L.

Chrozophora rottleri (Gels.) Spr.

Charozophora prostrata

Euphorbia hirta L.

Euphorbia microphylla Roth

Euphorbia prostrata Alt,

Phyllanthus fraternus Webster

Phyllantus maderaspatensis L.

Phyllanthus virgatus Forst

FABACEAE: LEGUMINOSAE (PAPILIONACEAE)

Alysicarpus longifolius W.&A.

Alysicarpus monilifer (L.) DC.

Alysicarpus rugosus (Willd.) DC.

Desmodium dichotomum (Willd.) DC.

Desmodium triflorum (L.) Dx.

Indigofera cordifolia Heyne

Indigofera linifolia (L.f.) Retz.

Indigofera glandulosa Willd.

Rhynchosia minima (L.) DC.

Sesbania bispinosa (Jacq.) W.F. Wight.

LAMIACEAE:

- *Leucas aspera* L.

LYTHRACEAE:

- *Amania baccifera* L.

MALVACEAE:

- *Abelmoschus esculentus* (L.) Moench.

MENISPERMACEAE:

- *Cocculus hirsutus* (L.) Diels.

MALVACEAE:

- *Glinus oppositifolius* (L.) A.DC.
- *Mollugo pentophylla* L.

OXALIDACEAE:

- *Biophytum sensitivum* ( ) DC.

PAPAVERACEAE:

- *Argemone mexicana* L.

POACAE: (GRAMINEAE)

- *Aristida depressa* Retz.
- *Brachiaria eruciformis* (Sm.) Griseb.
- *Cynodon dactylon* (L.) Pers.
- *Dactyloctenium aegyptum* (L.) P. Beauv.
- *Dichanthium aristatum* (Poir.) Hubb.
- *Digitaria ciliaris* (Retz.) Koeler
- *Dinebra retroflexa* (Vahl) Pauz.
- *Echinochloa colona* (.) Link
- *Eragrostis diarrhena* (Schult.) Steud.
- *Eragrostis poaeoides* Beauv.
- *Eragrostis tremula* Hochst.
- *Eragrostis uniloides* (Retz.) nees ex Steud.

PORTULACACEAE:

- *Portulaca oleracea* L.
- *Trianthema portulacastrum* L.
- *Trianthema decandra* L.

RUBIACEAE:

- *Oldenlandia aspera* (Roth) DC.
- *Oldenlandia corymbosa* L.

SAPINDACEAE:

- *Cardiospermum halicacabum*

SCROPHULARIACEAE:

- *Sopubia delphinifolia* (L.) Don
- *Striga asiatica* (L.) Kuntze

APPENDIX - II

A LIST OF ICRISAT WEED RESEARCH PUBLICATIONS

1. Agronomy and Weed Science - Reports of Work 1976, 1977, 1978. Farming Systems Research Program, ICRISAT, Hyderabad, India.

2. Binswanger, H.P., and S.V.R. Shetty, 1977. Economic Aspects of Weed Control in Semi-Arid Tropical Areas of India. Proc. Weed Sci. Conf. 1977. Ind. Soc. Weed Sci. APAU. Hyderabad, India p. 75-91.

3. Davies, E.L.P. 1978. The Potential for Introducing Improved Weed Control Methods to Small Farmer of the Indian Semi-Arid Tropics. A dissertation submitted for Master of Agricultural Science (Tropical Agricultural Development) at Univ. of Reading. Reading, U.K., p. 86.

4. Kanwar, J.S. 1978. Weed Research in India - Whither! Valedictory address delivered at the 1978. Ann. Conf. of Ind. Soc. Weed Sci. Coimbatore, Feb. 3-5, 15 p.

5. Krantz, B.A. 1978. Weed Management Research in the Semi-Arid Tropics. Key note address delivered at the 1978 Ann. Conf. of Ind. Soc. Weed Sci. Coimbatore, Feb. 3-5, p. 10.

6. Moody, K. and S.V.R. Shetty, 1979. Weed Management in Intercropping Systems. Paper presented at the International Workshop on Intercropping, ICRISAT, Hyderabad, India. Jan. 10-13, p. 30.

7. Rao, M.R. and S.V.R. Shetty, 1976. Some biological aspects of Intercropping Systems on Crop-Weed Balance. Ind. J. Weed Sci. 8 : 32-34.

8. Shetty, S.V.R. 1976. Possible approaches to weed management in sorghum. Pesticides Information, 2(3) : 72-80.

9. Shetty, S.V.R. 1977. Multicrop herbicide screening - Preliminary evaluation on major semi-arid tropical crops, Proc. Weed Sci. Conf. 1977. Ind. Soc. Weed. Sci. APAU, Hyderabad, India. p. 240-241.

10. Shetty, S.V.R. 1978. Some observations on weed intensity and crop management systems, Environ. Physiol. Ecol. Plants : 145-155.

11. Shetty, S.V.R. 1979. Weed control in sorghum in the tropics. Paper presented at the 10th Ann. Meeting. Weed Sci. Soc. Philip. Manila, May 3-6, p. 14.

12. Shetty, S.V.R. and B.A. Kratz, 1979. Weed Research at ICRISAT. Paper presented at the International Session of the 1979 Ann. Meeting, of WSSA, San Francisco, CA, Feb. 12 p.

13. Shetty, S.V.R. and A.N. Rao, 1979. Weed management studies in Sorghum/Pigeonpea and pearl millet/groundnut intercrop systems - Some observations. Paper presented at the International Workshop on Intercropping. ICRISAT, Hyderabad, India, 10-13, Jan. 15 p.

14. Shetty, S.V.R. and M.R. Rao, 1977. Weed management studies in pigeon-pea based intercropping. Paper presented at the 6th Asian Pacific Weed Science Society Conference, Jakarta, Indonesia, July 11-17, 25 p.

15. Shetty, S.V.R., B.A. Kratz, and S.R. Obien. 1977. Weed Research Needs of the small farmers. Proc. of Weed Sci. Conf., Ind. Soc. Weed Sci., APAU, Hyderabad, India. p. 47-60.