II.1.3 Upland Crops in the Hot Dry Season

(1) Maize variety trial (1991)

1) Objectives

To select early maturing maize varieties suitable for the cropping system before late rice planting.

2) Materials and methods

Field:	Namushakende Farm Institute NF-1, NF-2
Varieties:	MM501, MM502, MM504, MMV400, POOL16
Seeding date:	7th and 21st of August
Planting density:	Row width 0.8 m, plant distance 0.3 m, 1 plant/hill
Fertilizer:	Lime 1 t/ha broadcasting Basal application; D'mix (10-20-10) 300 kg/ha Top dressing; Urea (46% N) 100 kg/ha
Plot size:	0.8 m x 4 rows x 6 m long = 19.2 m^2 (3 replications)
Spraying of pesticide:	Sumicidin 20% emulsion, 30 m lit./10 lit. water Spraying date; After 2 weeks and 4 weeks of germination date for each plot

3) Results and discussion

The maize crops suffered lightly from drought injuries because it didn't rain for about 2 months after seedling and because of the absence of irrigation facilities. Also, plant growth was restrained and the heading date was slightly delayed. The date of maturity was delayed, too, and grain-filling was restrained due to shortage of sunshine hours and wet injuries due to field flooding which resulted from heavy rains in the later part of November in contrast with the drought in the early stage. The growth and yield data are shown in Table II.1.3.1.

Since Pool 16 and MMV400 are early maturing varieties, they were harvested before the 10th of December, which is the final harvest date of dry season crops in this cropping system, even if they were sown on the 23rd of August; however, the yield of these early maturing varieties was rather low. On the other hand, the MM501, MM502 and MM504 varieties showed possibility of giving high yields of about 3 ~ 4 t/ha. However, their growth was a little slow, and their maturing date was after the 15th of December when they were sown on the 23rd of August.

Based on the 3 years trials, the following can be concluded on the assumption that the final date for harvest is the 10th of December.

The varieties of MM60 series will not be used in the cropping system, because although these varieties have high yielding ability, their growing period is too long.

If seeding is possible before the middle of August, MM500 series are recommendable. However, it is difficult to say what variety among the MM500 series is best except for the fact that MM502 has higher resistance against streak virus.

(2) Water saving trial of maize and pearl millet on sandy soil field

1) Objectives

To study water saving cultivation technology of maize and pearl millet on sandy soil which has low water retention capacity.

2) Materials and methods

Field: Lealui S-1-1

Varieties: MM504 (maize), LBC (millet)

Seeding date: 16th of August

Planting density: Maize; Row width 0.8 m, plant distance 0.3 m, 1 plant/hill

Pearl millet; Row width 0.8 m, plant distance 0.2 m, 2 plants/hill

Fertilizer: Basal application; D'mix (10-20-10) 200 kg/ha, stable manure 800 kg/ha

Top dressing; D'mix 200 kg/ha (100 kg for millet) + Urea (46% N) 50 kg/ha

Watering method:

Division	Duration	Watering Quantity	Watering Quantity per Day	Total Water
A	From seeding day To 70th day	10 mm/every 5 days	2.0 mm	260 mm
	From 71st day To 110th day	15 mm/every 5 days	3.0 mm	
B	From seeding day To 70th day	10 mm/every 3 days	3.3 mm	431 mm
	From 71st day To 110th day	15 mm/every 3 days	5.0 mm	

Watering was carried out by using watering cans.

Spraying of pesticide: Sumicidin 20% emulsion, 30 m lit./10 lit. water

Spraying date; After 2 weeks and 4 weeks of germination date for each plot

3) Results and discussion

The grain yield of the maize did not increase with lots of watering, although the weight of the leaves and stem increased (see Table II.1.3.2). On the other hand, the grain yield of pearl millet increased with lots of watering (see Table II.1.3.3), and this process mainly contributed to the increase of the number of the fertile ears. Much watering contributed mainly to increase the number of the fertile ears of pearl millet.

By watering the maize with 260 mm of water during one cropping, 6 t/ha of dried grain was gained, while pearl millet produced only 2 t/ha of dried grain even if it was watered 430 mm during one cropping. Therefore, maize is considered to be more favorable than pearl millet for water saving culture on fields with sandy soils.

It is also necessary to study the possibilities of more water saving maize cultivation.

(3) Grain crop variety trials on sandy soils (1989)

1) Objectives

To investigate the adaptabilities of grain crop varieties and their growth response to fertilizers in sandy soils.

2) Materials and methods

Field:	N-2 (2,500 m^2)	
Crops and varieties:	Maize	MV400, MMV600, MM603, MM604
	Millet	LBC, NC-D_2, 1CMW 82/32
	Sorghum	WSV187, WSV387
Fertilizer:	Basal	1) No fertilizer 2) Cow manure (dried) 250 kg/ha 3) D'mix 400 kg/ha 4) Cow manure 250 kg + D'mix 400 kg/ha
	Top dressing	D'mix 200 kg/ha in all plots
Seeding date:	27th August	
Planting density:	Row width 0.8 m, plant distance 0.3 m, 1 plant/hill, 41,700 plants/ha	
Plot size:	0.8 m x 6~7 rows x 10 m long = 48 ~ 56 m^2 10 varieties x 4 treatments = 40 plots (no replication)	

3) Results and discussion

Plant growth 73 days after planting is shown in Table II.1.3.4. In plots without fertilizer applications, growth was extremely stunted and a number of maize plants failed to extract tassel. The growth in plots with manure application was somewhat improved but the nutritional effect of the manure was low. Whereas, chemical fertilizer (D'mix) applications remarkably increased plant growth and maximum growth was found in plots with D'mix plus manure application. The appearance of fertilizer deficiency in D'mix application plots one month after planting was improved with top dressing. Appearance of the same symptoms in D'mix plus manure plots was slower compared with those in D'mix plots. This might have been caused by retentive effect of manure for chemical fertilizer as well as nutrient supplies in the manure itself.

Growth and yield at harvesting time are indicated in Table II.1.3.5. Millet and early maturing maize matured in early December whereas the others in late December. Grain yield data were irrelevant due to damage caused by stem borers. It is impossible to evaluate the effects of fertilizer on grain yield.

Further trials on fertilizing practices for grain crops in sandy soils will be necessary, but depending on the results, it is assumed that it is necessary to apply 300 kg/ha of manure. As described above, millet and early maturing varieties of maize may be adaptable for the double cropping with rice.

(4) Grain crop variety trials on thick peat-muck soils (1989)

1) Objectives

To investigate the growth behaviour and fertilizer response with varieties of maize, millet and sorghum on thick peat-muck soils.

2) Materials and methods

Field: E-2 (2,500 m^2)

Crops and varieties:	Maize	MMV400, MMV600, MM603, MM604
	Millet	LBC, NC-D_2
	Sorghum	WSV187, WSV387

Seeding date:	First sowing 12th August Second sowing 27th August
Seeding method:	Row width 0.8 m, plant distance 0.3 m, 1 plant/hill 41,700 plants/ha
Fertilizer:	Lime application (1.5 t/ha) to all plots. Basal dressing .... Maize D'mix 300 or 600 kg/ha, millet & sorghum D'mix 200 or 400 kg/ha Top dressing .... Urea 87 kg/ha in all plots
Plot size:	0.8 m x 6 row x 10 m long = 48 m^2 (no replication)

3) Results and discussion

a) The first seeding trial

The growth of the three crops were favourable in their early stages, however, one month after planting, some plants showed pale green leaves and growth retardation. These disorders occurred in most plots regardless of species, varieties and fertilizer application. The disorders were low in millet and high in maize and sorghum. The sorghum plants with severe symptom mostly died during the middle stage of growth. The growth of affected plants was poor and their flowering time delayed.

Table II.1.3.6 shows the growth and yield at harvesting time. The maturing date of millet was early December and was the earliest of the three crops. That of maize was mid to late December. Maturing date of sorghum was not determined due to damage of stem borer after flowering. Growth response to fertilizer application was determined in the middle stage of growth when growth was superior with heavy fertilization. In the early maturing varieties of maize and millet, the grain yield was 1 ~ 1.7 t/ha and the effects of increased fertilizer application appeared. In late maturing varieties, maize yields were very low and there were no grain yields for sorghum due to insect damage and growth inhibition.

b) The second seeding trials

Growth retardations and insect damages were similar. Growth and yields are shown in Table II.1.3.7. The maturing time of early maize and millet was around the 10th of December and the others were in early January. The days to maturity for the second sowing were shortened by 10 ~ 15 days for the early varieties and about 5 days for the late varieties as compared with the first sowing. Grain yields were very low due to late sowing and insect damage.

c) Observations from the first and second sowing trials

i) The adaptability to peat-muck soils were best for millet followed by maize and worst in sorghum.

ii) The early planting of early maturing varieties may be necessary for the introduction of double cropping with rice and for escape of insect damages.

iii) The increased application of fertilizer seems to be effective in higher grain yields on thick peat-muck soils for early maturing varieties of maize and millet.

(5) Early maturing pearl millet variety trial (1991)

1) Objectives

To select early maturing pearl millet varieties suitable for the cropping system before late rice planting.

2) Materials and methods

Field:	Namushakende W-3
Varieties:	Varieties introduced from ICRISAT; ICMV88907, ICMV88908, ICMP87703
	Control variety; LBC

Seeding date:	27th of September
Planting density:	Row width 0.8 m, plant distance 0.2 m, 2 plants/hill
Fertilizer:	Lime 1 t/ha broadcasting Basal application; D'mix (10-20-10) 200 kg/ha Top dressing; Urea (46% N) 50 kg/ha
Plot size:	0.8 m x 4 rows x 4.2 m long = 13.44 m^2 (3 replications)
Spraying of pesticide:	Sumicidin 20% emulsion, 30 m lit./10 lit. water Spraying date; After 2 weeks and 4 weeks of germination date for each plot

3) Results and discussion

ICMV88907 and ICMV88908 were introduced from ICRISAT and are short growing varieties whose growth from sowing to maturity take 95 days, 8 day earlier than the control variety LBC. The yield of both varieties was more than twice as much as LBC (see Table II.1.3.8).

If seeding of maize can not be carried out before late August due to field condition and/or seasonal labor shortage, etc., these pearl millet varieties are recommendable for late rice - cereal cropping system in place of maize. The productivity and other characteristics of both varieties are nearly the same.

Although the ICMP87703 variety was considered to be highly productive last year, it was not so in this trial. Instead, the yield observed was only higher than LBC.

(6) Planting time trial of tomato (1991)

1) Objectives

To study suitable planting time of tomato for the cropping system before late rice planting.

2) Materials and methods

Field: Namushakende W-2

Variety: Red Kaki

Planting Time	Seeding Date	Planting Date	Row Width	Plant Distance
First planting	July 21	Aug. 29	0.7 m	0.5 m
Second planting	Aug. 8	Sept. 16	0.7 m	0.5 m
Third planting	Aug. 26	Sept. 28	0.7 m	0.5 m

Fertilizer: Lime 1 t/ha broadcasting
Basal application; D'mix (10-20-10) 500 kg/ha
Top dressing; D'mix 100 kg/ha

Plot size: 0.7 m x 5 rows x 6 m long = 21 m^2
(3 replications)

3) Results and discussion

The earlier the planting date was, the higher the yield of fruits became in this trial, because the period from the planting to the harvesting of Red Kaki took about 2 months and half. The harvest period even for those planted early is only limited to one month, and the potential productivity of tomatoes was not used effectively. By prolonging the harvest period to 20 more days, the yield increased to more than 50% (see Table II.1.3.9).

Therefore, if Red Kaki is used it should be planted by early August. For early planting, it is necessary to study the use of the heat insulation seed bed which enables seeding early in July. It is also necessary to select early maturing varieties with shorter growth period.

(7) Tomato variety trial (1991)

1) Objectives

To select suitable tomato variety for the cropping system before late rice planting.

2) Materials and methods

Field:	Namushakende W-2
Varieties:	Red Kaki (Zambian variety), Magokoro (Japanese variety)
Seeding date:	26th of August
Planting date:	28th of September
Planting density:	Row width 0.7 m, plant distance 0.5 m, 1 plant/hill
Fertilizer:	Lime 1 t/ha broadcasting Basal application; D'mix (10-20-10) 500 kg/ha Top dressing; D'mix 100 kg/ha
Plot size:	0.7 m x 6 rows x 4.75 m long = 20 m^2 (2 replications)

3) Results and discussion

The delay in the delivery of the seeds caused delayed seeding and planting of varieties, hence, the total production was not ascertained. However, the essential trend was understood.

Magokoro, the Japanese variety, was harvested a week earlier than Red Kaki (see Table II.1.3.10). However, the Zambian people, who prefer sour tomato more, do not favor the taste of Magokoro. Therefore, other suitable varieties should be introduced.

Disbudding accelerates the onset of the harvest period a week earlier than usual and also products larger fruits. Therefore, the prolongation of the harvest period through early planting and disbudding is desirable to be carried out until suitable early growing varieties are found.

(8) Seeding time trial of sweet corn (1991)

1) Objectives

To study suitable seeding time of sweet corn for the cropping system before late rice planting.

2) Materials and methods

Field:	Namushakende W-2
Varieties:	Honeybantam 20
Seeding date:	14th of August, 4th and 25th of September
Planting density:	Row width 0.8 m, plant distance 0.3 m, 1 plant/hill
Fertilizer:	Lime 1 t/ha broadcasting Basal application; D'mix (10-20-10) 300 kg/ha Top dressing; Urea (46% N) 50 kg/ha
Plot size:	0.8 m x 5 rows x 8.1 m long = 32.4 m^2 (3 replications)
Spraying of pesticide:	Sumicidin 20% emulsion, 30 m lit./10 lit. water Spraying date; After 2 weeks and 4 weeks of germination date for each plot

3) Results and discussion

The growth of the plants sown on the 14th of August and the 4th of September was restrained. This is mainly attributed to drought injuries resulting from the absence of rain from early August to early October. However, no significant difference was recorded in the cob yield (see Table II.1.3.11).

Allowable seeding time of this variety is rather long because it is possible to harvest cob within 85 days from seeding. Mid-September would be the optimum time for the seeding of this variety, on the assumption that the final date for dry season crops is the 10th of December.

(9) Pulses trial (1990)

1) Objectives

To select early maturity pulses suitable for the cropping system after late rice planting.

2) Materials and methods

Field:	Namushakende W-1, W-2
Crop:	Cowpea, Contender bean, Bambara bean, Ground nuts
Seeding date:	17th of August
Planting density:	Cowpea; Row width 0.5 m, plant distance 0.2 m, 1 plant/hill
	Ground nuts; Row width 0.8 m, plant distance 0.3 m, 1 plant/hill
	Other pulses; Row width 0.6 m, plant distance 0.2 m, 1 plant/hill
Fertilizer:	Basal application; Lime 1,000 kg/ha, D'mix (10-20-10) 300 kg/ha
Plot size:	100 m^2 (no replications)

3) Results and discussion

The results are shown in Table II.1.3.12.

Cowpeas (local variety), bambara beans (local variety), Ground nuts (local variety) and soybeans (introduced 6 varieties) did not mature 4 months after seeding. Therefore, these pulses are not adaptable for the cropping system for late rice-cereal. The cowpeas (Sakimidori: Japanese variety) maturing 3 months after seeding are not also adaptable for the cropping system because it has a very poor yield.

Contender beans are promising because of their early maturing and rather high yielding characteristics. However, based on last year's trial, they were found to have a low tolerance to acid soil. The yield increasing techniques on acid soils, including peat-muck soils, therefore, should be investigated. Soybean got pods in all six varieties but were all sterile owing to physiological disorder.

Table II.1.3.1 Growth and Yield of Maize Varieties

(1) Seeding of 7th of August

Item	MM 501	MM 502	MM 504	Pool 16	MMV 400
Days to heading 1)	86	88	90	74	81
Maturing date	Dec. 8th	Dec. 10th	Dec. 10th	Dec. 1st	Dec. 5th
Length of stem cm	98.2 ± 2.6	100.0 ± 2.2	96.5 ± 2.3	69.7 ± 0.8	75.4 ± 1.0
F.W. of one plant 2) g	192.2 ± 71.5	249.0 ± 27.5	227.9 ± 22.8	74.9 ± 9.9	93.3 ± 5.4
F.W.of one cob g	232.4 ± 22.5	284.4 ± 18.1	272.1 ± 7.0	128.5 ± 27.8	151.1 ± 4.2
No. of fertile cob 3)	1.0 ± 0	1.0 ± 0	0.96 ± 0.04	0.82 ± 0.04	0.90 ± 0.02
Yield 4) kg/ha	2967 ± 291 b	3586 ± 281 a	3253 ± 394 ab	1522 ± 217 c	1926 ± 35 c

LSD = 934 kg/ha, LSD = 606 kg/ha

1) Number of days from seeding to heading.
2) Fresh Weight of stem and leaves per plant.
3) Number of fertile cob per plant.
4) Yield of dry grain.
5) Different mark of a,b,c, indicates significant differences

(2) Seeding of 21st of August

Item	MM 501	MM 502	MM 504	Pool 16	MMV 400
Days to heading 1)	81	81	86	70	75
Maturing date	Dec. 15th	Dec. 15th	Dec. 18th	Dec. 5th	Dec. 10th
Length of stem cm	102.3 ± 6.1	103.7 ± 5.3	102.3 ± 6.8	70.5 ± 1.8	73.4 ± 0.3
F.W. of one plant 2) g	210.3 ± 4.7	248.0 ± 21.2	246.7 ± 11.0	95.5 ± 8.8	120.6 ± 6.7
F.W.of one cob g	293.3 ± 16.8	300.0 ± 23.9	296.3 ± 20.5	146.1 ± 16.3	186.1 ± 5.7
No. of fertile cob 3)	1.01 ± 0.01	1.01 ± 0.01	1.00 ± 0	1.00 ± 0	1.03 ± 0.02
Yield 4) 5) kg/ha	4153 ± 387 a	3884 ± 359 a	3490 ± 366 a	1824 ± 233 b	2303 ± 170 b

LSD = 1323 kg/ha, LSD = 858 kg/ha

Table II.1.3.2 Relationship between Watering Quantity and Yield of Maize

Item	Watering A	Watering B
Days to heading 1)	76	75
Length of stem cm	130.1 ± 4.5	132.1 ± 4.5
F.W. of one Plant 2) g	245.6 ± 8.0	320.6 ± 33.7
F.W. of ong cob g	303.3 ± 11.6	315.6 ± 22.0
No. of fertile cob 3)	1.10 ± 0.04	1.02 ± 0.01
Yield 4) kg/ha	6329 ± 351	6283 ± 307

1) Number of days from seeding to heading
2) Fresh Weight of stem and leaves per plant.
3) Number of fertile cob per plant.
4) Yield of dry grain. No significant difference

Table II.1.3.3 Relationship between Watering Quantity and Yield of Pearl Millet

Item	Watering A	Watering B
Days to heading 1)	80	68
Length of stem cm	129.9 ± 4.8	145.9 ± 2.4
F.W. of one Plant 2) g	192.6 ± 12.6	210.4 ± 15.6
F.W. of ong cob g	67.0 ± 12.7	95.9 ± 5.9
No. of fertile cob 3)	2.77 ± 0.17	3.19 ± 0.06
Yield 4) kg/ha	1641 ± 292	2222 ± 253

LSD $_{0.05}$= 534 kg/ha

1) Number of days from seeding to heading
2) Fresh Weight of stem and leaves per plant.
3) Number of fertile cob per plant.
4) Yield of dry grain.

Table II.1.3.4 Growth of Grain Crop Varieties in Sandy Soil 73 days after Planting

(on Sandy Soil, 1989)

Crops	Varieties / Fertilizers	Plant height (cm)	No. of leaves	No. of tillers	Plant height (cm)	No. of leaves	No. of tillers
		MMV 400			MM 604		
Maize	No fertilizer	39	10.5	0	47	9.8	0
	Manure	53	12.3	0	62	10.5	0
	D'mix	104	14.9	0	110	15.6	0
	Manure + D'mix	109	17.4	0.4	135	16.9	0.3
		MMV 600			MM 603		
	No fertilizer	34	9.2	0	49	10.5	0
	Manure	46	10.9	0.1	47	10.0	0
	D'mix	97	16.8	0	92	17.3	0
	Manure + D'mix	138	15.8	0.2	89	17.9	0.3
		ICMW 82/32			NC - D2		
Millet	No fertilizer	38	8.3	2.2	49	10.7	1.7
	Manure	80	8.9	3.6	47	8.4	2.8
	D'mix	132	9.5	6.8	92	11.7	8.5
	Manure + D'mix	148	10.3	10.9	89	11.4	8.6
		L B C					
	No fertilizer	41	10.7	1.7			
	Manure	59	10.4	4.7			
	D'mix	137	10.9	10.1			
	Manure + D'mix	157	11.4	12.1			
		WSV 187			WSV 387		
Sorghum	No fertilizer	37	9.5	0	43	7.6	0
	Manure	57	10.6	0.1	49	8.8	0
	D'mix	76	12.7	0.4	94	11.9	1.4
	Manure + D'mix	110	14.2	1.4	91	12.7	0.5

Table II.1.3.5 **Growth and Yield of Grain Crop Varieties in Sandy Soil at Harvesting Time**

(On Sandy Soil, 1989)

Crops & Varities	Fertilizers	Harvesting date	Fresh Plant weight kg/a	No. of ear/hill	Ear weght g/hill	Grain yield kg/a
Maize MMV400	No fertillizer	16/12	20	0.8	35	2.22
	Manure	23/12	19	1.0	51	6.95
	D'mix	7/12	47	1.1	72	7.23
	Manure + D'mix	7/12	76	1.0	87	6.12
MMV600	No fertillizer	2/12	11	0.5	7	-
	Manure	26/12	39	0.6	16	-
	D'mix	21/12	89	1.3	79	1.95
	Manure + D'mix	21/12	125	1.4	147	11.7
MM 604	No fertillizer	21/12	17	0.7	13	-
	Manure	26/12	39	0.6	28	0.56
	D'mix	21/12	102	0.9	84	2.8
	Manure + D'mix	21/12	118	1.7	96	3.6
Millet ICMW 82/83	No fertillizer	12/12	8	1.1	8	0.14
	Manure	8/12	20	1.0	19	3.3
	D'mix	11/12	26	1.3	29	6.7
	Manure + D'mix	5/12	61	2.4	55	12.8
L B C	No fertillizer	12/12	13	1.1	1.5	2
	Manure	7/12	18	1.3	12	1.4
	D'mix	6/12	67	2.6	69	14.5
	Manure + D'mix	5/12	93	-	99	19.7
NC - D2	No fertillizer	10/12	6	0.9	12	1.1
	Manure	7/12	12	1.1	13	2.3
	D'mix	6/12	59	2.3	66	12.2
	Manure + D'mix	7/12	66	2.3	69	11.9
Sorghum WSV 187	No fertillizer	26/12	28	1.0	7	2.8
	Manure	2/12	39	1.0	13	0.56
	D'mix	28/12	125	1.1	28	0.8
	Manure + D'mix	28/12	150	1.0	37	3.3
WSV 387	No fertillizer	26/12	16	1.0	7	0.56
	Manure	21/12	28	1.0	13	0.8
	D'mix	12/12	59	0.9	39	6.1
	Manure + D'mix	12/12	56	1.1	43	7.2

Table II.1.3.6 Growth and Yield of the First Sowing Grain Crops at Harvesting Time

(on Thick Peat-muck Soil, 1989)

Crops	Varieties	Fertilizer D'mix kg/ha	Earing date	Maturing date	No. of ear/hill	Fresh ear weight g/hill	Fresh plant weight kg/a	Grain yield kg/a
Maize	MMV 400	300	30/10	3/12	1.1	127	66	13.9
		600	21/10	4/12	2.1	219	101	16.9
	MMV 600	300	8/11	23/12	2.1	207	121	6.7
		600	2/11	12/12	2.6	213	159	5.0
	MMV 603	300	3/11	12/12	1.9	145	107	1.7
		600	3/11	23/12	2.7	223	120	3.3
	MMV 604	300	2/11	12/12	0.9	119	117	11.1
		600	10/11	23/12	2.1	201	125	4.4
Millet	LBC	200	26/10	6/12	5.3	41	117	1.39
		400	3/11	6/12	5.5	95	183	3.75
	NC - D2	200	3/11	6/12	3.4	76	77	6.67
		400	2/11	6/12	4.3	102	111	10.15
Sorghum	WSV 187	200	9/11	4/1	1.0	11	60	-
		400	14/11	4/1	0.6	21	73	-
	WSV 387	200		4/1	1.0	15	58	-
		400		4/1	1.0	19	72	-

Table II.1.3.7 Growth and Yield of the Second Sowing Grain Crops at Harvesting Time

(on Thick Peat-muck Soil, 1989)

Crops	Varieties	Fertilizer D'mix kg/ha	Earing date	Maturing date	No. of ear/hill	Fresh ear weight g/hill	Fresh plant weight kg/a	Grain yield kg/a
Maize	MMV 400	300	3/11	12/12	1.6	79	38	0
		600	-	13/12	1.5	104	61	3.34
	MMV 600	300	16/11	4/1	1.5	125	106	1.67
		600	14/11	3/1	1.7	239	173	5.56
	MMV 603	300	-	4/1	2.1	261	136	2.50
		600	-	4/1	1.7	153	99	0.83
	MMV 604	300	-	4/1	2.5	337	206	11.12
		600	14/11	-	-	-	-	-
Millet	LBC	200	12/11	10/12	2.8	37	117	0.83
		400	10/11	10/12	3.7	65	111	0.78
	NC - D2	200	10/11	8/12	2.1	21	65	0.28
		400	6/11	8/12	4.5	53	145	2.22
Sorghum	WSV 187	200	-	4/1	0.2	5	44	0
		400	-	4/1	0.1	3	83	0
	WSV 387	200	-	4/1	0.7	12	36	0
		400	-	4/1	1.3	64	122	2.78

Table II.1.3.8 Growth and Yield of Early Maturing Pearl Millet Varieies

Item	ICMV 88907	ICMV 88908	ICMP 87703	L B C
Days to heading 1)	59	59	67	67
Maturing date	Dec. 28th	Dce. 28th	Jan. 5th	Jan. 5th
Length of stem cm	145.0 ± 7.6	162.1 ± 14.2	173.2 ± 7.7	162.6 ± 8.8
F.W. of one plant 2) g	206.3 ± 34.3	245.9 ± 57.7	233.0 ± 5.5	279.6 ± 31.4
No. of fertile ear 3)	3.14 ± 0.19	2.99 ± 0.27	2.30 ± 1.22	1.24 ± 0.53
Yield 4) kg/ha	2384 ± 266	2389 ± 151	1500 ± 222	1069 ± 176

1) Number of days from seeding to heading.
2) Fresh Weight of stem and leaves per plant.
3) Number of fertile ear per plant.
4) Yield of dry grain.

Table II.1.3.9 Relationship between Planting Date and Yield of Tomato

(1) A case to limit the harvesting period at the 10th of December

Item	Planting Date		
	Aug. 29th	Sept. 16th	Sept. 28th
Harvesting period	Nov. 13 - Dec. 10	Nov. 26 - Dec. 10	Dec. 5 - Dec. 10
No. of fruits/100m2	1891 ± 119	767 ± 153	248 ± 136
F.W. of one fruit g	119 ± 2.6	146 ± 11	170 ± 2
F.W. of fruit t/ha	22.53 ± 1.84	11.32 ± 3.22	4.20 ± 2.31

(2) A case to Prolong the harvesting period till the End of December

Item	Planting Date		
	Aug. 29th	Sept. 16th	Sept. 28th
Harvesting period	Nov. 13 - Dec. 28	Nov. 26 - Dec. 28	Dec. 5 - Dec. 28
No. of fruits/100m2	3458 ± 396	2310 ± 263	1319 ± 30
F.W. of one fruit g	102 ± 7	126 ± 6	133 ± 19
F.W. of fruit t/ha	35.15 ± 2.38	29.20 ± 3.84	17.57 ± 2.72

Table II.1.3.10 Yield of Tomato Varieties

Item	Red Kaki	Red Kaki (Disbudding)	Magokoro (Disbudding)
Harvesting period	Dec. 12 - Dec. 28	Dec. 5 - Dec. 28	Nov. 30 - Dec. 28
No. of fruits/100m2	394 ± 95	722 ± 39	1069 ± 317
F.W. of one fruit g	71 ± 6	93 ± 2	117 ± 1.4
F.W. of fruit t/ha	2.85 ± 0.89	6.66 ± 0.23	12.52 ± 3.83

Table II.1.3.11 Relationship between Seeding Date And Yield of Sweetcorn

Item	Planting Date		
	Aug. 14th	Sept. 4th	Sept. 25th
Harvesting date	Nov. 3 - Nov. 6	Nov. 23 - Nov. 26	Dec. 12 - 15
No. of growing days 1)	82 - 85	81 - 84	79 - 82
Length of stem cm	73.9 ± 6.6	84.8 ± 3.1	100.5 ± 5.0
F.W. of one cob g	156.7 ± 26.3	156.7 ± 11.9	213.3 ± 25.1
No. of cob /100m2	384.3 ± 13.2	430.7 ± 33.9	426.0 ± 26.5
F.W. of cobs t/ha	60.0 ± 6.6	67.3 ± 3.6	93.1 ± 9.1

1) From seeding date to harvesting date.

Table II.1.3.12 Growth and Yield of Pulses

Crops	Seeding date	Flowering date	Maturity date	Grain Yield kg/ha
Cowpea (Zambian)	Aug. 17	-	-	-
Cowpea (Japanese)	Aug. 17	Oct. 4	Nov. 10	180
Contender bean	Aug. 17	Oct. 4	Nov. 10	246
Ground nuts	Aug. 17	Oct. 8	Jan. 3	701
Banbara bean	Aug. 17	Oct. 18	Jan. 8	590

II.2 Guideline of Farming System

II.2.1 On Farm Trials

(1) Objectives

Trials were aimed at examining an adaptability of component technology of crop production for farmer's field and also scheming the feedback of production constraints arisen via on-farm trial to JICA/AVS farm.

(2) Agreement with the host farmer

This on-farm trial was carried out on the condition that JICA/AVST provided a free seed and fertilizer to the host farmer who agreed to offer labor force and allowed JICA/AVST to sample his field for a yield estimation. The products were left to the host farmer.

(3) Outline of on-farm sites

The outline of four sites where on-farm trial was carried out is as followed:

1) Soil aspect

Table II.2.1.1 The Result of Soil Analysis in Each On-farm Site

Site	Soil Text	pH [$CaCl_2$]	Al (ppm)	P	K (me/100 g)	Ca	Mg	Cu	Zn (ppm)	Fe	NH_4	NO_3
NFI	SCL	4.4	9.2	16	0.05	2.1	0.5	11	9.0	583	4.0	0.0
Sufula	SL	4.2	1.9	30	0.14	0.4	0.8	-	1.0	96	2.0	3.4
Mabumbu	LS	4.1	4.6	4	0.07	0.6	0.1	-	3.0	280	19.6	17.6
Naela	SCL	4.5	7.0	2	0.23	1.8	0.7	4	7.0	1364	18.0	0.0

Note: SCL; Sandy clay loam, SL; Sandy loam, LS; Loamy sand

2) Landscape, management and profile of the host farmer

a) Namushakende farm institute (Sandy loam soil)

This site is located within the Government land where JICA/AVS Namushakende farm is located. The structure of this field, irrigable by plot-to-plot irrigation system constructed during the colonial era of Great Britain, has been demarcated by levees and rice is widely cultivated by transplanting method. The field permitted by NFI has a hard pan with well-decomposed mucky soil where gravitational irrigation method is possible but drainage is difficult. The history of rice cultivation here is quite long, more than 40 years, mostly cultivated by the staff of NFI who were allowed to cultivate. Their common practical method is only to apply 200 kg of D'mix as a basal dose.

(b) Mabumbu village (Loamy sand soil)

This site is located between Limulunga and Mongu, where rice is produced and slightly outer plain of the Sishanjo band in the edge of Zambezi flood plain, and is easily accessible. A quadrant sampling in the site was done by JICA/AVST last year after giving an improved rice seeds to the local farmer at planting time. The profile of the host farmer is as follows:

Mr. Mubyana Likezoh (31 years, possessing 5 ha over five sites, five year experience in rice cultivation, self-employee is only their couple). He is one enterprising young farmer, possessing 6 oxen, oxen plow with zig-zag harrow and oxen sledge. Main source of his income is derived from selling maize, sorghum, rice, vegetables, and for charging local fields for oxen plow operations. Water source for the site is rain water and overflow water from the near canal, which makes the field flood usually around 10 cm in a normal year and 30 cm in abnormal flood years. As a conventional cultural practice, only cattle manure is applied because of no initial fund to procure chemical fertilizer. Plowing and harrowing are done by oxen combined with broadcasting of rice seeds of only local varieties. The production constraints perceived by the host farmer are 1) damage due to disease and insects, 2) lack of technical guideline for farming, 3) lack of initial fund for planting.

c) Naela village (Sandy clay loam soil)

Details of the host farmer:

Name:	Mr. Alfred M. Kabange (40 years old)
Land:	About 20 ha (regular arable area is about 5 ha)
Major soil and soil pH:	Sandy clay loam, pH = 4.5 Labor force: husband and wife, son + temporary employee
Major crops cultivated:	Rice, maize, vegetables
Management of agriculture crops:	A surplus is sold to middle-merchant or Agricultural cooperative union
Agricultural tools possessed:	Oxen-plow, harrow, ox-sledge 6 heads of ox, 13 heads of fattening cattle
Irrigation source:	Rain, flood water, canal water available from late January
Fertilizer practice:	No fertilizer practice done so far because of high potential fertility
Management of rice straws:	Used for cattle grazing after picking panicles, burning straw residuals followed by plowing operation.
Soil management practice:	Plowing the field on every June & September and broadcasting rice seed at plowing time on mid-December.
Recognition of production constrains by host farmer:	Lack of labor force, lack of efficient transportation mean, lack of seeds with jump price, lack of vaccine to prevent cattle disease

(4) Materials and methods

Field:	1) Namushakende farm institute (sandy clay loam soil in Sishanjo soil band of plain edge) 2) Mabumbu village (sandy loam soil in Mataba-Sitapa band) 3) Naela village (sandy clay loam soil in Saana zone)
Test variety:	Angola crystal, Xiang Zhou 5
Experimental design:	1,250 m^2, no replication
Sowing date:	1st year; NFI December 11 Naela December 18 2nd year; NFI November 19 Sefula November 21 Mabumbu December 20 Naela December 19
Seed rate:	60 kg/ha via selection with water, 30 cm row space
Weeding practice:	When it necessary

[1st year]

Fertilizer:	Basal dressing, D'mix 250 kg/ha at sowing time Top dressing, Urea 40 + 40 kg/ha at tillering and meiosis

[2nd year]

Fertilizer:	Basal dressing, D'mix 250 kg/ha at sowing time a. Top dressing, Urea 40 + 40 kg/ha at tillering and meiosis stage b. Top dressing, Urea 60 + 60 kg/ha at tillering and meiosis

(5) Summary

[Namushakende farm institute/90-9]

This trial was conducted in the Sishanjo soil band of the plain edge, where JICA AVS farm was located, to compare with yield level at JICA AVS farm. The soil of trial site is dominantly composed of muck soil including silt and clay with hard pan and classified as a sand clay loam soil. The soil pH was 4.4 (by $CaCl_2$) and a single rice cropping was done every rainy season. Irrigation is only possible to get water from a closed canal via plot to plot irrigation method but impossible to drain at all. Most weeds observed were dominantly grasses, cyperaceae and broad-leaf weed. The growth characteristic and the grain yields were shown in Table II.2.1.2. The grain yields of both varieties Xiang Zhou 5 and Angola crystal was 697.4, and 560.6 gm/m^2 respectively. This high yield was quite different from that of JICA/AVS farm and appears to be highly originated from soil physico-chemical aspect.

The period of sowing operation (seeding on dry bed) in the Sishanjo band is relatively short due to its soil bearing capacity at beginning of rainy season. Thus it is recommendable to be done by late November in combination with oxen plow. In addition, developing an efficient drill seeder by manual type is considered as a key point to extend a line sowing method.

[Naela village/90-91]

In the Western Province where many peasant farmers were majority, the host farmer, where on-farm trial was conducted, possessed 15-20 ha, so-called "Emergent farmer". His farming way is based on animal draught power (in terms of plowing and harrowing). The field was heavy, sandy clay loam soil and many soil clods like fist size remained with dried grass roots at sowing time. This made furrowing for seeds difficult. Dominant weeds observed were gramineous and cyperaceous weed, but very less broad leaf weeds. Flood level in the field reached to 47 cm on mid-February. Urea was applied one time before flooding. In early April, lodging was seen in Angola crystal in the 4 scale of 2. The result of the grain yields and growth characteristics was shown in Table II.2.1.3.

Both Xiang Zhou 5 and Angola crystal varieties performed high yield level of 561.4 and 408.8 gm m^2 respectively. And Xiang Zhou 5, short culm variety was verified to be grown under flood condition of 47 cm depth. The problems arisen via this on-farm trial is a necessity of developing drill seeder and extending it urgently in order to seed a large area efficiently. Most farmers who were interviewed complained that they could not afford to employ a method of line sowing because of its labor intensive and very painful to bend their waist at sowing time, in spite of recognizing its advantages.

Furthermore, aiming at high yielding technology on rice production, a labor competition between maize (dry season maize) and rice in rainy season are not inevitable issue for future extension.

[Namushakende farm institute/91-92]

Drilling on dry soil was done on November 19. A uniform emergence was established 10 days after sowing but weeds also grew rapidly, thus requiring two weeding practice during the 3 weeks preceding flooding.

Then the 1st topdressing, urea was applied. The damage caused by rats and black maize beetles (BMB) started from early December, thus flooding the plot was enforced from mid December to eradicate them. The rice plants flowered in mid February and matured late March. Table II.2.1.4 shows the results of the final growth and grain yield. No clear difference to N-level was found in the grain yield, but the yield level turned out 5 t/ha - 5.3 t/ha which was 10 ~ 30% less than that of last year.

This field, dominant loam clay soil, has a hard pan layer which enables oxen plow operation till late December of the rainy season if drainage is possible.

[Mabumbu village/91-92]

This site, classified as Sitapa band with dominant soil of loamy sand, is cultivated with maize, sorghum and rice in the rainy season on elevated area of its topography. Drilling on dry bed was done on December 20, after plowing and harrowing by oxen, which was easy under good drainage condition like Sefula site. Rat damage broke out 2 weeks later after sowing. Also some damaged plants like dying-off of new leaves was observed, but no pest was found. Rat damage, which break out two different growth stages; namely at emergence and ripening stage, was mitigated by applying a lure crop method, namely by scattering rice gains around the field. The pest damage being apprehended was almost over, but leaf blast came out in Angola Crystal plot when high humidity weather with cool temperature during night continued in February. Further, this leaf blast developed into panicle blast, which caused a severe yield reduction. Local varieties are quite sensitive to rice blast disease when grown under upland condition.

The blast disease was out of control, because this severe drought weather made the field upland condition through the cropping season. However, Xiang Zhou 5 showed a resistance to blast disease, and the degree of stress damage was also slighter than that of Angola crystal under this severe drought spell.

That is, observing the root system of both varieties, Xiang Zhou 5 reached up to 40 cm depth but Angola crystal was only around 20 cm depth. From this fact, Xiang Zhou 5 was proved to be superior to local varieties (Angola crystal) in terms of drought tolerance. The final growth and grain yields are given in Table II.2.1.5. Xiang Zhou 5 under this severe drought weather exceeded 5 t/ha, but Angola crystal yielded less than 4 t/ha with a low percentage of filled grains (50%), because of stem borer and panicle blast occurrence at grain filling period.

As the result of computing rough balance of cost and return (Table II.2.1.6), Xiang Zhou 5 brought 184,099 kW/ha, and Angola crystal did 121,736 kW/ha, with considerable profits. The local rice fields around the on-farm trial site was mainly cultivated without chemical fertilizer, thus an initial growth was slower than that of on-farm trial and severely influenced by the harsh drought weather which started early February. Meanwhile, the rice plants grown in this on-farm trial plot resisted against severe water stress in the late growth stage and brought high yields. This fact attracted local farmers around this trial site and a field day was organized on April 21 by inviting local farmers.

Table II.2.1.2 The Result of the Grain Yield & Growth Characteristics for NFI On-Farm Trial

(1990/91)

Cultivar	Grain Yield (gm/m2 at 14%)	No. of Panicles (per m2)	No. of Panicles (per m2)	% of Filled Grain (%)	1000 Grain weight (gm)	Culm Length (cm)	G/S Ratio	Growth Duration (days)
Xiang Zhou 5	697.4	365.3	26492.7	85.5	30.9	55.9±4.7	1.86	116
Angola Crystal	560.6	349.3	22961.9	80.0	30.5	89.6±6.9	1.24	118

Table II.2.1.3 The Result of the Grain Yield & Growth Characteristics for Naela On-Farm Trial

(1990/91)

Cultivar	Grain Yield (gm/m2 at 14%)	No. of Panicles (per m2)	No. of Panicles (per m2)	% of Filled Grain (%)	1000 Grain weight (gm)	Culm Length (cm)	G/S Ratio	Growth Duration (days)
Xiang Zhou 5	561.4	379.0	26503.3	78.8	27.0	85.0±4.7	0.65	114
Angola Crystal	408.8	390.7	15995.8	79.0	32.3	123.0±7.1	0.51	119
Angola Crystal (Local method)	372.6	-	-	86.3	-	95.7±6.5	0.78	-

Table II.2.1.4 The Result of the Yield Analysis at Namushakende Farm Institute

Item	Xiang Zhou 5		Angola Crystal	
	N-61.8	N-80.2	N-61.8	N-80.2
Grain/Straw ratio	1.6	1.4	1.03	1.19
Culm lengh (cm)	50.1±1.6	52.5±4.7	88.8±6.7	90.6±7.6
No. of Panicles (/m2)	333.3	298.6	263.3	245.8
1,000 GWT (gm)	29.3	30.8	30.2	30.4
No.of Spiklets/m2	22400	20997.2	17715.7	23548.5
% of filled grain (%)	80.2	84.2	87.5	75.9
Grain Yield (gm/m2)	527.1	543.2	507.6	504.7
Growth duration (days)	125	125	132	132

(91/92 Season)

Table II.2.1.5 The Result of the Yield Analysis at Mabumbu On-Farm Trial

Item	Xiang Zhou 5		Angola Crystal	
	N-61.8	N-80.2	N-61.8	N-80.2
Grain/Straw ratio	0.96	0.87	0.42	0.29
Culm lengh (cm)	49.1±3.3	49.5±3.7	86.1±8.7	81.5±10.6
No. of Panicles (/m2)	509.3	370.6	461.3	354.6
1,000 GWT (gm)	25.6	28.3	26.3	27.2
No.of Spiklets/m2	30716.5	23883.0	30186.8	34372.1
% of filled grain (%)	72.9	75.5	49.6	38.5
Grain Yield (gm/m2)	574.1	510.9	392.6	359.7
Growth duration (days)	114	114	123	123

(91/92 Season)

Table II.2.1.6 The Result of Cost and Return Analysis for Mabumbu On-Farm Trial

(per ha)

Item	Amount Input	Unit Price	Cost (/ha)	Xiang Zhou 5	Angola Crystal
Fertilizer					
D'mix	250 kg	16 kw/ka	4000 kw		
Urea	100 kg	16 kw/kg	1600 kw		
Sub Total			5600 kw		
Seeds	60 kg	37.5 kw/kg	2250 kw		
Labor					
Oxen plow	4 head oxen	-			
Oxen harrow	- ditto -	-			
Leveling		-	2000 kw		
Drilling	87 hrs.	28.6 kw/ha	2488 kw		
Weeding			4000 kw		
Fertilizer	10 hrs.	- ditto -	1001 kw		
Harvest		-			
Threshing/winnowing		-			
Sub Total			19339 kw		
Sale Amount of paddy rice (3000kw/80kg bag)				5425 kg/ha 203438 kw/ha	3762 kg/ha 141075 kw/ha
Net return				184099 kw/ha	121736 kw/ha

Note : "Net return" does not include the cost of depreciation for agricultural tools like hoe, sickle, etc. Labor charge was computed based on the figure for JICA Namshakende farm wage system excluding self-employed's wage by the farmer.

II.3 Guideline of Useful Component Technology

II.3.1 Sowing Methods in Sandy Soil

(1) Objectives

Trials were aimed at examining methods to improve the rate of seedling establishment and plant growth in sandy soil.

(2) Materials and methods

Field:	Lealui S-1-1/1,100 m^2	
Experimental design:	RCBD with 3 replications	
Test variety:	Burma	
Seed rate:	60 kg/ha via selection of water, 3 cm row space	
Sowing date:	December 31	
Treatment:	a. Deep seeding furrow + dry grass mulching + side dressing	
	b. Deep seeding furrow + dry grass mulching + broadcasting	
	c. Line maker + dry grass mulching + broadcasting (control)	
	d. Line maker + dry grass mulching + side dressing	
Fertilizer application:	Basal dressing;	D'mix 200 kg/ha, manure 2 t/ha
	Top dressing;	Urea 43.5 + 43.5 kg/ha (Total-N = 40 kg/ha) before flooding

(3) Summary

After applying cattle manure at the end of December, drilling on dry soil was done after making seeding furrow based on the treatments, and then mulching the plots with dry grass. The treatment of deep seeding furrow (TDSF) to the control resulted in high percentage of emergence (significant at the 5% level), and the effect of deep seeding furrow (Table II.3.1.1) was verified. However, the weather of high humidity with cool temperature at night in late tillering stage caused a severe leaf blast, which spread over all plots, and developed into panicle blast at heading stage. In addition, white head due to stem borer occurred in many places, adversely affecting the treatment effects. Thus, this pest and disease problems led to the result of no treatment difference statistically. But the treatments 1 and 2 of deep seeding furrow appears to be more productive than that of treatments 3 and 4 of seeding on flat bed by the line maker (See Table II.3.1.2). Thus, provided that a proper cultural practice is enforced by suppressing insect and disease occurrence from emergence stage, more yield will be expected from the sowing method on deep seeding furrow.

Table II.3.1.1 The Percentage of Emergency

(Lealui Farm : 1991/92)

Treatment	Rep 1	Rep 2	Rep 3	Mean
1) DSF + SD + DGM	42.0	53.7	57.7	51.3
2) DSF + BC + DGM	53.3	51.7	57.7	54.2
3) LM + BC + DGM	37.7	28.3	43.3	36.4
4) LM + SD + DGM	38.3	48.0	40.7	42.3

LSD 0.05 = 12.03

Note :
DSF Deep Seeding Furrow
LM Line Maker
SD Side Dressing
BC Broadcasting
DGM Dry Grass Mulching

Table II.3.1.2 The Results of the Cultural Practice Trial

(Lealui Farm : 1991/92)

Treatment	Grain Yield (gm/m2)	No. of Panicles/ m2	Grain Straw Ratio	Culm Length (cm)
1)	214.5	252.2	0.51	64.8±4.6
2)	239.2	237.2	0.66	68.2±6.1
3)	209.8	280.0	0.56	60.3±5.3
4)	210.4	258.3	0.51	65.7±6.8

II.3.2 Rice Straw Incorporation on Paddy Rice Cultivation

(1) Objectives

Trials were aimed at examining methods of soil improvement on peat-muck soil and methods of fertilizer application.

(2) Materials and methods

Field: Namushakende E-1 (2,200 m^2)

Experimental design: Split plot design with 2 replications
Only sand soil dressed plot has 2 reps.

Variety: Late maturing variety P1369

Planting space: 22.2 stocks/m^2 (row space 30 cm, hill space 15 cm)

Transplanting date: December 23-24

Soil improvement method:

a) Sand dressed test plots
Rice straws were incorporated into the western half of the test plots during the dry season.

b) No sand dressed test plots
Rice straws were incorporated into the western half test plots and the plot dressed with clay soil last year remained intact.

Note: Abbreviation

SDRS; sand dressed + rice straw incorporation

SDNRS; sand dressed + no rice straw

NSDRS; no sand dressed + rice straw incorporation

NSDNRS; no sand dressed + no rice straw

Fertilizer application: Total-N is 76 kg/ha in both plots treated with rice straws;

a: Standard dosage treatment;

Basal dressing; NPK = 30:60:30 kg/ha at emergence

Top dressing; N (26 + 26) kg/ha at tillering & meiosis b: Standard dosage treatment + K-topdressing

Basal dressing; NPK = 30:60:30 kg/ha at emergence

Top dressing; N (26 + 26) kg/ha at tillering & meiosis

Top dressing; K (30) kg/ha at meiosis

c: Heavy dosage of top dressing treatment + K-topdressing

Basal dressing; NPK = 10:60:30 kg/ha at emergence

Top dressing; N (33 + 33) kg/ha at tillering & meiosis

Top dressing; K (30) kg/ha at meiosis

Each of N, P, K elements is based on urea, triple superphosphate and potassium sulfate.

(3) Summary

The growth differences in tillering began one month after transplanting among the rice straw treatments, regardless of the sand dressed treatments. The plant growth of SDRS and NSDRS plots showed very vigorous tillering with dark fresh green leaves and the least dying-off from lower leaves. However fading leaf color in SDNRS and NSDNRS began with an inferior growth of the plant height associated with brown spot occurrence in late February.

In late growth stage, panicle blast severely broke out more in the sand dressed plots (SDP) than in the sand free-plot (SFP). Tables II.3.2.1 and II.3.2.2 give the results of final growth and grain yield. A pooled mean yield of SDRS in E-1-1 resulted in 538.8 gm/m^2, which was 145% increase compared to 219.8 gm/m^2 in SDNRS plots. E-1-2 similarly increased 43%. Both results were statistically significant at the 5% level. Comparing the yield of SDP with that of SFP in the no rice straw treated plots, the grain yield of SDP was only 54% of that in SFP. This implies that the sand dressing effect to increase crop yields does not last any more. Keeping a constant level of total nitrogen amount, no difference resulted between the treatments stressing basal dressing and topdressing with potassium fertilizer, and no effect of potassium topdressing either. Table II.3.2.3 shows the result of the soil chemical analysis based on the treatment in E-1-2. The effect of rice straw incorporation to increase crop yields should be, of course, considered with tissue analysis results. However, looking at the result of soil analysis alone, concentration of Mg, K, Na and P was 2 to 3 times higher in the rice straw treated soil, and this appeared to be a key factor to increase grain yield.

Table II.3.2.1 The Result of Grain Yield Analysis in Soil Improvement Trial

(Namshakende Farm : 1991/92 E-1-1 (Sand Dressing)

Treatment of Rice Straw Incorporation	Topdressing Method	Grain Yield (g/m2)*	No. of Panicles/ m2	Grain/Straw Ratio	Main Culm Length (cm)
+ Rice Straw	a	518.3	196.7	1.23	49.6±4.2
	b	567.6	168.9	1.49	51.9±4.1
	c	530.6	201.1	1.30	49.1±3.9
- Rice Straw	a	227.5	132.2	0.87	42.2±3.9
	b	218.5	147.8	0.88	33.2±3.1
	c	213.6	136.7	1.10	35.0±3.1

* LSD 0.05 = 94.2 g/m2

Tested Variety : P1369

Table II.3.2.2 The Result of Grain Yield Analysis in Soil Improvement Trial

(Namshakende Farm : 1991/92 E-1-1 (No Sand Dressing)

Treatment of Rice Straw Incorporation	Topdressing Method	Grain Yield (g/m2)*	No. of Panicles/ m2	Grain/Straw Ratio	Main Culm Length (cm)
+ Rice Straw	a	565.1	183.3	1.36	49.9±3.0
	b	595.5	214.4	1.28	51.7±5.1
	c	575.0	216.2	1.11	51.8±3.1
- Rice Straw	a	399.2	176.7	1.20	45.1±5.8
	b	384.4	150.0	1.18	46.4±4.0
	c	427.1	190.0	1.10	47.8±3.4

* LSD 0.05 = 94.2 g/m2

Tested Variety : P1369

Table II.3.2.3 The Result of Soil Chemical Analysis

No.	Field	Treatment	(me/100g)				(ppm)						me/100g
			Ca	Mg	K	Na	Zn	Mn	P	Cu	Fe	NH4-N	CEC
1	E-1-2	+ Rice Straw	16.2	2.1	0.24	0.10	130	20.0	60	4.0	1160	3.7	71.7
2		+ Rice Straw	13.4	1.8	0.12	0.10	860	22.0	31	5.0	1470	4.8	69.9
3		- Rice Straw	11.4	0.5	0.09	0.07	1190	14.0	17	6.0	1100	4.9	73.3
4		- Rice Straw	13.4	0.9	0.08	0.06	450	20.0	24	2.0	1120	5.0	63.1

II.4 Countermeasures of Production Constraints

II.4.1 Improvement of Peat-Muck Soils

(1) Lime application trial on peat-muck soils (Rice 1989/90 - 1991/92)

1) Objectives

Trials were aimed at examining an optimal dosage of lime to amend soil acidity of peat-muck soil, and the necessity of continuous lime application.

2) Materials and methods

[1st year]

Farm:	Namushakende (E-5-1:1,100 m^2)	
Experimental design:	No replication, 22 m x 11.7 = 25.7 m^2	
Variety:	IR8192	
Sowing date:	January 6	
Seed rate:	60 kg/ha via selection with water, drilling on wet bed with 30 cm in between rows	
Lime treatment:	Zero, 1 t/ha, 2 t/ha, 3 t/ha	
Fertilizer application:	Basal dressing;	D'mix 300 kg/ha at sowing
	Top dressing;	Urea 20 kg/ha at tillering
		Urea 50 kg/ha with V'mix at tillering
		Urea 30 kg/ha at meiosis

[2nd year]

Experimental design:	Split plot without replication
Test variety:	Late maturity type of IR8192

Planting density: 22.2 stocks/m^2 (Row space 30 cm, hill space 15 cm)

Transplanting date: February 4

Lime treatment:

i) Zero plot in last year; a) Zero, b) lime 1.5 t/ha, c) burnt rice straw (5.5 t/ha)

ii) 1-3 t/ha in last year; a) Zero, b) 1.5 t/ha

Fertilizer:

Basal dressing; D'mix 300 kg/ha at transplanting

Top dressing; Urea 50 + 50 kg/ha at tillering & meiosis stage

[3rd year]

Experimental design: Split plot without replication

Test variety: Late maturity type of IR8192

Transplanting date: December 17

Plant density: 22.2 stocks/m^2 (Row space 30 cm, hill space 15 cm)

Lime treatment:

89-90	90-91	91-92
Zero	1.5 t/ha	1.5 t/ha
		Zero
	rice straw burnt --	rice straws burnt
1, 2, 3 t/ha	1.5 t/ha	1.5 t/ha
		Zero
	Zero	1.5 t/ha
		Zero

Fertilizer application:

Basal dressing; D'mix 300 kg/ha at emergence

Top dressing; Urea 50 + 50 kg/ha at tillering & meiosis stage

Note: Lime treatment must be done precisely.

3) Summary

[89/90]

This trial was carried out in a newly constructed field. Pregerminated seeds were sown on wet soil due to soil condition but sowing operation was tough. Emergence was well uniform but the plants of the lime zero treatment plot (LZP) turned into yellowish-brown discoloration of leaves 10 days after emergence. Further this symptom became more severe and 80% of the canopy disappeared on month later. The results of soil pH and monitoring of tillering capacity over time are shown in Table II.4.1.1.

Soil pH of 1 and 2 t/ha lime plots was almost similar to LZP; however, the growth and development was markedly different from that of LZP. No tillering increment over time in LZP was observed from the stage of emergence and begun to drop from late February, while other treated plots increased rapidly, then begun to decrease from mid March. Among lime treated plots, 3 t/ha lime plot changed with the highest tillering number over time.

No grain was produced in LZP but other lime treatments resulted in no differences of the grain yield with no closed relation between number of panicles and grain yield (Table II.4.1.2). From these results, by applying lime ionic balance among soil mineral elements appeared to be amended.

[Lime application trial/1990-91]

1) Summary

From 2nd week after transplanting, the community of lime zero plot (LZP) from the previous lime treatment (LZP in 1st year) begun to turn into brownish from old leaf tips and partly disappeared by late March. The community treated by rice straw burnt was also stunted with a same symptom but disappeared slightly. The lime applied plot followed by zero treatment first year showed a fair growth. Furthermore, LZP followed by 1-3 t/ha lime plots this year in plant growth but partially showing brownish symptom. However, the lime effect was clearly verified in the culm length and the grain yields except the number of panicles/m^2 (Table II.4.1.3), but the grain yields and the culm length were superior to LZP in this year. For instance, the grain yields of LZP this year was 153.1 gm/m^2 which was 47% less than that of continuous lime applied plots (CLAP).

From this fact, getting a stable grain yield level, it requires an annual lime application because of the dropping lime effect within one year. Rice straw burning treatment (RSBT) burnt about 5.5 t/ha of rice straw, computed from G/S ratio 0.6 in last IR8192 yield performance, but inferior to that of lime effect. Liming plots this time followed by LZP last year showed an effect of lime but inferior to the plot of consecutive liming. Thus further observation is necessary.

[Lime application trial/1991-92]

1) Completing liming treatments and rice straw burning, transplanting operation was executed on December 17. The rice plants of LZP showed a symptom of browning lower leaves in mid January and indicated a sign of extinction. On the contrary, the plant growth of RSBT plot was comparable to that of alternative lime treated plot (ALTP), even lower leaves turning into brown more or less. The rice plants of LZP died partially but recovered later by shooting new leaves, even though plant growth was delayed. Table II.4.1.4 shows the results of the final growth and grain yield.

The grain yield of LZP was 285.5 gm/m^2, a least level among the treatments. Apart from LZP, other treatments ranged between 350 gm/m^2 and 380 gm/m^2, indicating no clear difference among the liming methods.

Reviewing the results of the past 3 years, LZP first year produced no grain because of the death of rice plants, but 2nd year yielded some grains (42.7 gm/m^2), then 3rd year more (285.5 gm/m^2) which became comparable to the liming plots. Meanwhile, the grain yield of consecutive liming plot yearly was higher than that of ALTP in the 2nd year, but the 3rd year resulted in no clear difference. Further, the effect of RSBT on grain yield 2nd year was inferior to the lime applied plot, but the 3rd year resulted in no clear difference. Generally, the yield difference among the lime treatments became smaller yearly, and this is considered as a change of physico-chemical aspects of the soils after field construction. Thus, it is recommended to continue further studies.

(2) Lime application trial on peat-muck soils (Hot dry season, 1989)

1) Objective

To investigate the effects of liming on peat-muck soils.

2) Materials and methods

Field:	E-3 (2,500 m^2)
Crops:	Maize (MMV500), Sorghum (WSV387), Cowpea, Banbara bean, Contender bean
Treatment:	Lime application (1.5 t/ha) or no lime
Fertilizer:	Basal; D'mix 300 kg/ha, Top dressing; Urea 40 kg/ha
Seeding date:	17th August
Seeding density:	Ridge width 0.8 m, plant distance 0.3 m/plant/hill, 41,700 plant/hill
Plot size:	0.8 m x 5 rows x 24 m long = 120 m^2 (no replication)

3) Results and discussion

In plots without lime (soil pH 4.2 ~ 4.5), growth was retarded in the early stage of growth and withered plants gradually increased. Table II.4.1.5 indicates the plants' survival percentage per plot 68 days after sowing. The survival percentage was highest for bambara bean followed by maize, less in the other crops, and was higher in plots with lime than in those without lime.

Lime application (soil pH 4.5 ~ 5.2) brought growth improvements for each crops as shown in Table II.4.1.6. However, the growth of maize and sorghum in this field (E-3) was poorer than in the variety trial fields (E-2). The soil conditions of this field may have been more unfavourable for plant growth than the variety field. Yield surveys were not performed because of the decrease in standing and poor growth.

It was supposed that soil improvement with lime applications and other procedures may be necessary for crop production in these fields with thick muck-peat soils. The comparative adaptabilities to this soil may be the highest for bambara beans followed by maize and very low for sorghum, contender beans and cowpeas.

(3) Tests for the analysis of growth disorders (Maize, 1989)

1) Objective

To clarify the cause of growth disorders in the fields with thick peat-muck soils, some surveys and small tests were carried out in the hot dry season.

2) Methods and results

Surveys and tests included soil pH, root system and influence of soil treatment as described below.

a) Soil pH

Soil samples at 5 cm under the surface were taken from 12 locations in the farm and the soils pH was determined on the 26th of September. In locations where the soil indicated a pH of 4.5 or less, the growth of crops was severely retarded. However, growth disorders were also found in locations with soils of a pH of more than 5. There may be many factors causing disorders other than the soils pH.

b) Investigation of maize root systems

The root systems of maize in E-2 and W-2 fields were surveyed using the Trench method on the 19th of October. The results were that the root systems of growth disorder plants in thick peat-muck soils (E-2) were distributed only within the upper layer of the top soils (within 8 cm). Whereas, the root systems of well grown plants in thin muck soils (W-2) widely and closely developed within a 12 ~ 13 cm depth from the surface and part of the roots extended up to 25 cm depth. The cause of growth disorders were suggested to be caused by the unsuitable physical and chemical conditions in the subsoils.

c) Soil treatment and plant growth

Shallow cultivation (about 8 cm depth) followed by immediate planting was compared with deeper cultivation (15 cm depth) followed by the drying of the soil for 10 days before planting on the 17th of October. As a result, 25 days after planting growth was apparently better in the latter than in the former. These results suggested that deep cultivation followed by soil drying may promote a decrease in the soil moisture, the oxidation of soil matter and the improvement of peat soils so that root can easily develop. This test should be repeated on a larger scale with replication for the next season.

(4) $CuSO_4$ application trials for wheat

1) Objectives

The peat-muck soil in Namushakende is acidic and copper deficiency symptoms are seen in wheat. As a countermeasure for copper deficiency $CuSO_4$ application trials were conducted.

2) Method and materials

a) No. 1 trial

Field:	Namushakende M-2-(2)	
Variety:	Jupateco	
Sowing date:	14th May	
Lime application:	1,500 kg/ha	
$CuSO_4$ application:	0, 10, 15, 20 kg/ha	
Sowing method:	Drilling with 0.25 m width level rows	
Fertilizer:	Basal application;	D'mix 300 kg/ha
	Top dressing;	Urea 100 kg/ha (3 weeks after emergence)
Plot size:	No replication, each 10 m x 2.4 m = 24 m^2	

b) No. 2 trial

Field:	W-1-(2)
Sowing date:	20th of August
$CuSO_4$ application:	0, 10, 15, 20 kg/ha
Plot size:	Two replications, each 5 m x 2.5 m = 12.5 m^2
Variety, sowing method, and fertilizer:	Same as the No. 1 trial

3) Results and discussion

In the No. 1 test, copper deficiency symptoms were seen in the non $CuSO_4$ plot. The results are shown in Table II.4.1.7. The field used for the tests has a thick peat-muck layer, so the yields were generally not so high. Although the yield levels were lower, the $CuSO_4$ application plots had higher yields than in the controlled plots, and within the $CuSO_4$ application plots the $CuSO_4$ application plots of 10 kg and 20 kg were the best.

In the No. 2 test, although cropped very late the tests were done to confirm the copper application effects. The results are shown in Table II.4.1.8. The ripened grain weight in the $CuSO_4$ application plots was heavier than in the non $CuSO_4$ application plots in block I, but it was unclear in Block II, and on average both blocks showed a tendency to be heavier in the application plots. The 1,000 grain weight showed a tendency to be heavier in parallel with the $CuSO_4$ application.

From the tests it was clear that the copper application was effective in alleviating the copper deficiencies of wheat. But as can be seen in the results the yield levels were low which may have been caused by the thick peat-muck layer in the test field. As already discussed in 2) and 3) it is necessary to take integrated countermeasures.

(5) Countermeasure trials for growth retardation in wheat (1991)

1) Objectives

To study countermeasures against micro nutrients deficiency, which easily occurs in peat-muck soil with high content of organic matters. (1991)

2) Materials and methods

Field:	W-1-(2)	
Varieties:	Loerie II	
Sowing date:	25th April	
Fertilizer:	Basal;	D'mix 300 kg/ha, $CuSO_4$ 30 g/10 m^2
	Top dressing;	Urea 85 kg/ha (3 weeks after emergence)
Liming:	1 t/ha	
Sowing method:	100 kg/ha, drilling with 25 cm level row width	
Plot size:	Split plot with three replications, one plot 12.5 m^2	

Treatment:

Nutrients	Amount of Application to Soil (g/10 m^2)	Foliar Application (%)
	(Three weeks after emergence)	(Five weeks after emergence)
Zn ($ZnSO_4 \cdot 7H_2O$)	10	0.5 lime 0.3
B ($Na_2B_4O_7 \cdot 10H_2O$)	3	0.3 lime 0.3
Mg ($MgSO_4 \cdot 7H_2O$)	100	0.3 lime 0.3
Mn ($MnSO_4 \cdot 4\text{-}5H_2O$)	100	0.3 lime 0.3
	(Foliar Application) (%)	
N ($(NH_4)_6Mo_7O_{24} \cdot 2H_2O$)	0.01	0.01
Fe ($Fe_2(SO_4)_3 \cdot 7H_2O$)	0.2	0.2

Plot size: One plot 10 m^2, two replications

3) Results

a) Growth situation

Emergence was disrupted by rats resulting in reseeding in some parts to get uniform emergence. After emergence, growth was uniform and no growth delay was recorded among treatments. Because of putting $CuSO_4$ in all plots there was no occurrence of copper deficiency. After the middle stage somewhat ununiform growth occurred making it difficult for proper sampling. There were no differences in heading date and maturing date among treatments.

b) Yields

Yields are shown in Table II.4.1.9. Yields of the Boron, Zinc and Ferric treated plots show somewhat higher values than that in the control plot. But, as described before, because of considerable ununiformity in growth retesting should be considered in the future.

(6) Comparison of copper deficiency occurrence in wheat among soils collected from surroundings of Mongu

1) Objectives

To study the effects of copper deficiency in wheat among several soils distributed in Mongu surroundings.

2) Materials and methods

Names of places where soils are collected:

1. Nacla near Limlunga	Soil	pH	6.5
2. Nongai in Mweke dambo	"	"	6.1
3. Namushakende Farm Institute-I	"	"	6.3
4. Namushakende Farm Institute-II	"	"	5.4
5. AVS Field E-3	"	"	4.5
6. AVS Field M-2	"	"	5.6
7. AVS Field W-3	"	"	5.4

Method of soil collection and method for test:

Soils of different sites were all previously used for paddy rice cultivation except for AVS field W-3 where upland crops were grown.

From the above mentioned sites soil samples were taken up to 20 cm depth. Each individual soil sample was used to filled up ditches prepared in AVS field W-3. The ditches were 20 cm deep, 45 cm wide and 160 cm long and will represent individual fields.

Variety:	Loerie II
Sowing date:	7th May
Fertilizer:	1) Control (lime 150 g + D'mix 50 g/m^2) 2) Copper plot (lime 150 g + D'mix 50 g + $CuSO_4$ 3 g/m^2) 3) Non fertilizer
Sowing method:	15 g/m^2, drilling with 13 cm between row, 3 rows per one plot
Plot size:	40 cm x 45 cm per one plot.

3) Results

a) Growth situation

Emergence in each soil was normal. Growth in non fertilized plots was retarded from early stage in every soil, especially, in non fertilized AVS-E3 soil plot which showed poor growth with yellowish leaves. Also in control plot, growth in AVS-E3 soil plot was inferior to other soil plots showing copper deficient symptoms on leaves. Control plots except AVS-E3 showed almost normal growth, and copper applied plots in all soils showed very good growth.

b) Straw weight and grain yields at maturing stage

The results are shown in Table II.4.1.10. Non fertilized plots in every soil were more or less inferior to corresponding fertilized plots. Among them, Limulunga soil shows better growth and more yield in non fertilized plot than other soils.

In control plots Limulunga, Mweke, and Farm Institute-I show more yields than other soils, and the former tow soils also showed much straw weight. On the other hand, AVS-E3 soil shows very little yield and straw weight almost similarly to the non fertilized plot.

Copper applied condition gives more straw weight and grain yields than the control plots in every soil, but the ratio to the control plots are differed among soils. The effect of copper application is less in Limulunga, Mweke, and Farm Institute-I which show more yields in the control plots, and more in Farm Institute-II, and all AVS soils.

4) Discussion

From the restricted conditions of non being able to displace large volumes of soil, the test could only be carried out on a small scale, but as seen the in above mentioned results, clear differences can be seen in growth and yield among soils.

Limulunga soil (sandy loam) shows best yield both in non fertilized and control (without copper) plots showing the most suitable soil for wheat cultivation. Mweke dambo soil and Farm Institute-I soil (both mucky soils) show better results following Limulunga control plots suggesting their suitability for wheat cultivation next to Limulunga soil. On the other hand, each AVS soil (peat-muck soil) and Farm institute-II soil (mucky soil) show copper deficiency resulting in the difficulties of getting normal growth under the control fertilization without copper. However, those soils excluding the AVS-E3 soil get more productivity by copper application showing the possibility of getting almost the same or more wheat yields compared to the above mentioned suitable soils. AVS-E3 soil is unsuitable for wheat because of its thick peat-muck layer although improvement of productivity will be somewhat expected through copper application (Table II.4.1.10)

In the edge area of the Zambezi flood plain there are mainly two kinds of soil areas; one is Sishanjo (peat-muck, acidic) bordering the shore ridge and the other is Mataba Sitapa (muck or sandy loam, weak acidic) bordering Sishanjo and spreading toward the center of the plain. The Limulunga is located in the Saana area. The Farm Institutes-I, II and the AVS-W3 are in the border between the Sishanjo and the Mataba Sitapa, and AVS-M2 and AVS-E3 are in the Sishanjo.

Although there are some difference between soils which exist in the same areas, it can be roughly said from the results of this trial that wheat cultivation in the Mataba Sitapa area can be considered somewhat easy. The same can be said concerning the Sishanjo excluding the area having thick peat-muck layer with poor drainage if proper liming is applied and some countermeasures against copper deficiency are taken.

Concerning the Mweke dambo soil, it is considered that the results may be generalized in this dambo are although some risks are considered in applying the results of only one soil sample.

(7) Yields increasing trial of maize on peat-muck soils (1991)

1) Objectives

The Namushakende farm is covered by peat-muck soils which are strongly acidic and hinder growth of Maize; it is often observed symptom of deficiency of micronutrients. This trial aims to increase the yield of maize through physiological improvement.

2) Materials and methods

Field : Namushakende M-4-2

Varieties : MMV400, Pool 16

Seeding date : 9th of August

Planting density:	Row width 0.8 m, plant distance 0.3 m, 1 plant/hill
Fertilizer:	Basal application; D'mix (10-20-10)300 kg/ha Top dressing; Urea (46% N) 100 kg/ha
Treatment:	① Lime; 3 t/ha, 1 t/ha, 0 t/ha ② Micronutrients; Zinc sulfate 20 kg/ha, Copper sulfate 30 kg/ha
Plot size:	0.8 m x 6 rows x 4 m long = 19.2 m^2
Spraying of pesticide:	Sumicidin 20% emulsion, 30 m lit./10 lit. water Spraying date; After 2 weeks and 4 weeks of germination date for each plot

3) Results and discussion

The effect of the application of zinc was found remarkable. However, the application of copper did not bring about any effect at all. The joint application of lime and zinc was found to be effective, and 3 t/ha of lime is more effective than 1 t/ha of lime (see Table II.4.1.11).

By applying 3 t/ha of lime, the pH value of the soil after 2 and 4 months was 6.5 and 5.0 respectively. This indicates an increase of 1.1 ~ 2.4 in the pH value of the soil by lime application. Meanwhile, the pH value rose to 5.2 from 4.1 after 2 months of 1 t/ha of lime application, and fell to 3.9 at after 4 months of the same application, indicating how insufficient 1 t/ha of lime is to correct soil acidity (see Table II.4.1.12).

The total zinc content of the soil was 4 to 7 ppm (see Table II.4.1.12). As a rule, less than 1.5 ppm of available zinc in the soil would lead to zinc deficiency in maize. It is, therefore, supposed that the greater part of zinc in this soil are unavailable.

It was made clear that the application of 20 kg/ha of zinc sulfate and 3 t/ha of lime on peat-muck soil field enables the increase in the yield of maize.

It is, therefore, important to conduct a study on methods of treatment to make available zinc from unavailable zinc in the soil.

Table II.4.1.1 The Result of Soil pH and Tillering Ability Over Time

(Namshakende Farm : 1989/90 Tested Variety : IR8192)

Lime Treatment	Soil pH	22/1	1/2	21/2	3/3	13/3	23/3	2/4	13/5
0 t/ha	3.9	73	75	78	60	58	42	64	0
1 t/ha	4.1	72	146	154	177	246	214	243	104
2 t/ha	4.2	77	148	159	189	253	235	267	133
3 t/ha	4.9	73	218	224	239	311	265	298	150

Note : Mean value of two sites of tiller numbers in 1 m row length

Table II.4.1.2 The Result of Grain Yield Analysis for Lime Application Trial of Late Maturing Variety

(Namshakende Farm : 1989/90 Tested Variety : IR8192)

Lime Treatment	Paddy Yield (g/m2)	No. of Panicles /m2	Grain /Straw Ratio	Culm Length (cm)
0 t/ha	-	-	-	-
1 t/ha	358.4	390.7	0.63	45.3±3.2
2 t/ha	314.4	326.7	0.57	47.4±4.1
3 t/ha	316.4	378.3	0.56	44.5±3.9

Table II.4.1.3 The Result of Lime Application Trial

(Namushakende Farm : 1990/91)

Lime Treatment		Grain Yield (g/m2)	Culm Length (cm)	Grain/Straw Ratio	No. of Panicles (/ m2)
Last Year	Current Year				
1 t/ha	1.5 t/ha	235.5	43.8±4.6	0.60	145.2
2 t/ha	1.5 t/ha	226.5	44.3±3.1	0.76	103.7
3 t/ha	1.5 t/ha	213.0	41.1±3.3	0.65	142.2
		X=225.0			
1 t/ha	Zero	125.9	37.5±4.6	0.34	124.4
2 t/ha	Zero	189.1	39.5±5.9	0.67	84.4
3 t/ha	Zero	144.5	38.0±3.7	0.42	180.6
		X=153.2			
Zero	Rice Straw burnt	99.7	41.3±4.8	0.22	145.2
Zero	1.5 t/ha	138.4	43.5±6.1	0.27	152.6
Zero	Zero	42.7	32.5±4.7	0.12	115.0

Tested Cultivar : IR8192 by Transplanting

Table II.4.1.4 The Result of Lime Application Trial

(Namushakende Farm : 1991/92 Tested Variety : IR8192)

Lime Treatment	Grain Yield (g/m2)	No. of Panicles/ m2	Grain/Straw Ratio	Main Culm Length (cm)
Alternative year application	349.1	142.2	0.88	58.9±6.1
First year only	388.9	132.2	0.90	62.1±7.1
First and second year only	350.7	105.5	1.19	55.9±5.7
Every year application	342.8	105.5	1.03	55.7±5.7
Second and third year application	381.9	182.2	0.78	56.1±4.5
Zero	285.5	93.3	0.92	45.5±4.5
Rice straw burning	386.9	124.4	1.09	56.2±6.0

Table II.4.1.5 Survival Percentage of Plants in Trials of Liming

Crops (Varieties)	Liming %	No liming %
Maize (MMV400)	66	52
Sorghum (WSV 387)	61	13
Contender bean	90	11
Banbara bean	87	81
Cowpea	61	35

Note : Survival plants 68days after planting

Table II.4.1.6 Growth 74 Days after Planting

Items	Liming			No liming		
Crops (Verieties)	Plant heigth cm	No. of leaves	Fresh plant weigth g/10 hills	Plant heigth cm	No. of leaves	Fresh plant weigth g/10 hills
Maize (MMV 400)	59	11.0	453	32	7.7	47
Sorghum (WSV 387)	30	6.5	33	+	+	+
Contender bean	49	14.5	267	+	+	+
Banbara bean	17	19.1	127	14	8.3	33
Cowpea	27	9.5	173	14	9.1	23

Table II.4.1.7 Effect of CuSO4 on Ripened Grain Weight and 1,000 Grain Weight of Extreme Late Sown Wheat

Item	Plot	Amount of CuSO4 (kg/ha)			
		0	15	30	45
Ripened grain weight (g/500 ears)	Block I	218	265	283	250
	Block II	210	200	180	230
	Average	214	233	232	240
1,000 grain weight (g)	Block I	23.2	24.8	26.2	27.4
	Block II	24.2	25.8	26.4	26.8
	Average	23.7	25.3	26.3	27.1

Table II.4.1.8 CuSO4 Application Trials for Wheat

Amount of CuSO4 kg/ha	Culm Length cm	Ear Length cm	No. of Ears /2m	Straw Weight kg/ha	Grain Yield kg/ha
0	43	7.2	115	768	342
10	46	6.8	127	750	926
15	53	7.6	104	796	936
20	49	7.4	122	750	690

Table II.4.1.9 Micro Nutrient Application Test for Wheat

Treatment	Maturing Date	Culm Length cm	Straw Weight t/ha	Grain Yield t/ha	1,000 Grain Weight
Control	24 Aug.	58	1.32	1.46	43.7
Mg	22 Aug.	55	1.47	1.60	46.0
Mn	21 Aug.	60	1.53	1.57	41.0
Zn	18 Aug.	61	1.28	1.71	41.7
B	21 Aug.	59	1.48	2.00	35.0
Mo	21 Aug.	56	1.47	1.53	42.3
Fe	23 Aug.	60	1.25	1.78	41.7

Table II.4.1.10 Growth and Yield of Wheat Cultured on Soils Collected from Surroundings of Mongu

Soil Collected Places	Treatment	Culm Length cm	Straw Weight g/40 cm2	Grain Yield g/40 cm2	Ratio to Control %	Ratio to Cu Plot %
Limlunga	Control	65	57	65.5	100	88
	Control + Cu	66	60	74.1	113	100
	Non fertilization	55	16	38.7	59	52
Mweke dambo	Control	63	57	53.1	100	95
	Control + Cu	66	62	55.7	107	100
	Non fertilization	42	12	6.5	12	12
Farm Institute I	Control	61	39	55.9	100	87
	Control + Cu	61	48	63.9	114	100
	Non fertilization	43	12	10.6	19	17
Farm Institute II	Control	60	35	42.7	100	39
	Control + Cu	68	82	109.4	256	100
	Non fertilization	41	6	9.7	23	9
AVS -E3	Control	31	9	2.3	100	7
	Control + Cu	54	28	34.5	1500	100
	Non fertilization	22	2	1.6	70	5
AVS - M2	Control	58	41	45.6	100	43
	Control + Cu	62	54	105.7	232	100
	Non fertilization	52	17	27.1	59	26
AVS - W3	Control	56	30	30.2	100	49
	Control + Cu	60	39	62.2	206	100
	Non fertilization	53	31	33.5	111	54

Table II.4.1.11 Effect of Zn, Cu and Lime on the Growth and Yield of Maize on Peat-Muck Soil

(1) MMV 400

Element	Days to heading 1)			Length of stem cm			F.W. of one plant 2) g		
	Ca 3t	Ca 1t	Non Ca	Ca 3t	Ca 1t	Non Ca	Ca 3t	Ca 1t	Non Ca
Zn	77	76	82	101.5	90.5	86.9	171.9	131.3	128.3
Cu	93	86	88	82.6	72.4	78.6	117.0	89.7	80.5
Non	93	88	93	76.5	72.1	67.3	101.4	90.9	62.0

Element	No. of fertile cob 3)			F.W. of one cob g			Yield 4) kg/ha		
	Ca 3t	Ca 1t	Non Ca	Ca 3t	Ca 1t	Non Ca	Ca 3t	Ca 1t	Non Ca
Zn	0.75	0.50	0.72	218.8	165.6	170.3	1172	1275	1042
Cu	0.71	0.67	0.56	85.6	84.6	71.9	537	573	553
Non	0.57	0.88	0.48	81.1	100.0	58.3	496	748	347

1) Number of days from seeding to heading.
2) Fresh Weight of stem and leaves per plant.
3) Number of fertile cob per plant.
4) Yield of dry grain.

(1) Pool 16

Element	Days to heading 1)			Length of stem cm			F.W. of one plant 2) g		
	Ca 3t	Ca 1t	Non Ca	Ca 3t	Ca 1t	Non Ca	Ca 3t	Ca 1t	Non Ca
Zn	73	72	72	91.6	78.6	82.5	146.9	84.4	70.3
Cu	86	82	82	78.8	71.4	75.6	80.7	61.4	65.1
Non	90	86	86	74.0	63.9	69.3	82.8	51.2	54.3

Element	No. of fertile cob 3)			F.W. of one cob g			Yield 4) kg/ha		
	Ca 3t	Ca 1t	Non Ca	Ca 3t	Ca 1t	Non Ca	Ca 3t	Ca 1t	Non Ca
Zn	0.97	0.63	0.56	196.3	106.3	93.8	1940	1094	964
Cu	0.72	0.63	0.60	78.1	52.6	62.7	724	702	684
Non	0.59	0.88	0.59	69.0	51.2	56.0	503	581	438

Table II.4.1.12 Results of Chemical Analysis of Experimental Plots

(1) Lime treatments (Sampling date : 1st of December)

Treatment	T-C	T-N	T-P	T-K	Av. P	Ex. Ca	Mg	Zn	Mn	CEC %
	%	%	me/100g	me/100g	ppm	me/100g	me/100g	ppm	ppm	me/100g
Lime 3 t/ha	7.32	0.30	144.3	0.09	63	8.9	0.9	7.2	2.8	16.64
Lime 1 t/ha	9.66	0.23	106.4	0.06	53	4.9	0.6	7.3	2.7	13.96
Non Lime	6.49	0.25	109	0.05	43	4.2	0.4	4.3	2.3	10.00

(2) Micronutrients treatments (Sampling date : 1st of December)

Treatment	T-C	T-N	T-P	T-K	Av. P	Ex. Ca	Mg	Zn	Mn	CEC %
	%	%	me/100g	me/100g	ppm	me/100g	me/100g	ppm	ppm	me/100g
Zn	9.49	0.34	152.4	0.08	66	6.6	0.8	4.0	3.0	22.59
Cu	10.81	0.32	89.3	0.07	39	6.9	0.9	7.3	3.7	28.08
Nothing	5.17	0.19	158.0	0.10	69	4.3	0.5	6.7	2.0	9.66

(3) Change of pH values with respect to time

Treatment	Oct. 1st	Dec. 1st
Lime 3 t/ha	6.5	5.0
Lime 1 t/ha	5.2	3.9
Non Lime	4.1	4.4

Lime application date is 8th o f August.

APPENDIX III

LAND CONSOLIDATION TECHNOLOGY FOR AGRICULTURAL PRODUCTION

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LIST OF FIGURES

III. LAND CONSOLIDATION TECHNOLOGY FOR AGRICULTURE PRODUCTION

III.1 Natural Conditions of The Plain Edge Area

(1) Soil texture and nature

1) Soil texture and pH

The investigations of soil texture and pH in the Sefula and Limulunga model area were carried out. These results are shown in Table III.1.1.

2) Soil permeability

The results of the soil permeability test in the both model areas and the Namushakende AVS farm are shown in Table III.1.2.

3) Ground bearing capacity

The result of the penetration resistance measurement are shown in Table III.1.3.

(2) Hydrology

1) Discharge of water resources

Monthly discharge fluctuations of the Sefula river and Namitome canal are shown in Table III.1.4 and Figure III.1.1.

2) Water level fluctuations in the model areas

Monthly water level fluctuations in the model areas are shown in Table III.1.5 and Figure III.1.2.

3) Water level fluctuations of the little Zambezi

Water level fluctuations of the little Zambezi at Matongo and Nawinda are shown in Table III.4.1, Figures III.1.3 and III.1.4.

4) Groundwater fluctuations at Namushakende and Lealui

Groundwater fluctuations at Namushakende and Lealui AVS farms are shown in Figures III.1.5 and III.1.6.

(3) Meteorology

1) Temperature and relative humidity

The data of monthly average maximum and minimum temperatures and relative humidity are shown in Table III.4.2. The comparison of the maximum and minimum temperatures at Mongu and Namushakende are shown in Figures III.1.7 ~ III.1.12.

2) Rainfall

The comparisons of rainfall data at Namushakende, Lealui, Mweke and Mongu are shown in Table III.1.5. The monthly rainfall values are shown in Figures III.1.13 ~ III.1.14. The differences between Namushakende and Lealui are shown in Table III.1.6.

Table III.1.1 Soil Texture and pH

Area	Soil type	Top soil		Upper sub-soil		Lower sub-soil	
		Texture	pH (H_2O)	Texture	pH (H_2O)	Texture	pH (H_2O)
Sefula	Mataba Sitapa	Sandy loam	6.5	Loamy sand	5.9	Sand	-
	Sishanjo	Muck	5.9	Muck loamy sand	6.1	Sand	-
Limulunga	Mataba Sitapa	Sandy loam	6.3	Loamy sand	5.6	Sand	-
	Sishanjo	Muck/ muck peat	5.9	Muck peat/ muck loamy sand	6.0	Sand/Muck peat	6.1
	Saana	Sand		Sand		Sand	
Namushakende	Sishanjo (Field E-7)	Muck peat	4.8				

Table III.1.2 Hydraulic conductivity of Soil

Measurement date	Area	Soil type	Groundwater level (GL. -m)	Hydraulic conductivity (cm/sec)
26 Sep. 1991	Sefula	Sishanjo	0.40	3.4×10^{-4}
03 Oct. 1991	Sefula	Mataba sitapa	0.60	2.1×10^{-3}
24 Sep. 1991	Limulunga	Sishanjo	0.30	1.0×10^{-3}
04 Oct. 1991	Limulunga	Sishanjo	0.60	1.2×10^{-3}
29 Apr. 1992	Namushakende	Sishanjo (Field E-4-1)	0.25	8.9×10^{-4}
30 Apr. 1992	Namushakende	Sishanjo (Field M-2-2)	0.10	2.4×10^{-3}
30 Apr. 1992	Namushakende	Mataba Sitapa/Saana (Field W-3)	0.55	2.6×10^{-3}

Table III.1.3 Values of Penetration Resistance in the Sishanjo Area

Depth (cm)	Sefula area (kg/cm^2)	Limulunga area (kg/cm^2)
5.0	0.32 ~ 1.41 (0.9)	0.32 ~ 1.60 (0.8)
10.0	0.77 ~ 4.16 (1.8)	0.51 ~ 4.48 (1.5)
15.0	0.64 ~ 6.40 (3.4)	0.58 ~ 6.40 (2.5)

Note: Values in ( ) show the average.

Table III.1.4 Monthly Water Discharges of Sefula River and Namitome Canal

Month/Year	Sefula river (m^3/s)	Namitome canal (m^3/s)	Rainfall at Mongu (mm)
Sep. 1991	0.30 ~ 0.35	0.27 ~ 0.29	-
Oct.	0.29 ~ 0.30	0.22 ~ 0.24	22.7
Nov.	0.27 ~ 0.34	0.25 ~ 0.50	56.6
Dec.	0.23 ~ 0.86	0.26 ~ 0.79	241.7
Jan. 1992	0.40 ~ 0.47	0.47 ~ 0.68	131.3
Feb.	0.21 ~ 0.53	0.28 ~ 0.44	103.8
Mar.	0.23 ~ 0.36	0.20 ~ 0.52	125.0
Apr.	0.26 ~ 0.32	0.22 ~ 0.41	12.3

Note: Feb. to April discharges values are underestimated as water is taken away for agricultural uses during these periods upstream of the observation point.

Table III.1.5 Monthly Water Levels in the Model Areas, 1991 ~ 1992

(Unit: m)

Month/Year	Sefula area		Limulunga area	
	GL. 1	GL. 2	GL. 1	GL. 2
Oct. 1991	Gl. -0.62 ~ -0.50	-0.85 ~ -0.61	-0.60 ~ -0.28	-1.63 ~ -1.59
Nov.	-0.54 ~ -0.27	-0.75 ~ -0.54	-0.01 ~ 0.15	-1.58 ~ -0.31
Dec.	-0.39 ~ 0.18	-0.62 ~ 0.22	0.02 ~ 0.33	-0.83 ~ 0.13
Jan. 1992	0.12 ~ 0.17	0.10 ~ 0.16	0.19 ~ 0.30	-0.09 ~ 0.09
Feb.	0.09 ~ 0.07	0.18 ~ 0.06	0.29 ~ 0.08	0.25 ~ -0.30
Mar.	0.06 ~ 0.12	0.15 ~ 0.08	-0.04 ~ 0.35	-0.54 ~ 0.24
Apr.	0.09 ~ 0.11	0.08 ~ 0.23	0.24 ~ 0.08	0.11 ~ -0.60

Note: GL.(-) shows groundwater level.
GL.1; Sishanjo
GL.2; Mataba Sitapa

Table III.1.6 Monthly Rainfall at Namushakende, Lealui, Mweke and Mongu

Month	Rainfall.			
	Namushakende	Lealui	Mweke	Mongu
06/1990	0.0	0.0	0.0	0.0
07/1990	0.0	0.0	0.0	0.0
08/1990	0.0	0.0	0.0	0.0
09/1990	2.5	0.0	0.0	1.0
10/1990	6.8	0.0	47.5	23.2
11/1990	95.0	67.3	57.6	66.9
12/1990	177.3	142.5	82.0	151.2
01/1990	205.5	177.3	134.9	239.5
02/1990	251.0	200.7	125.1	289.0
03/1990	100.7	153.8	56.6	143.9
04/1990	0.0	0.0	0.1	0.0
05/1990	0.0	0.0	0.0	0.0
Sub-Total	838.8	741.6	503.8	914.7
06/1991	0.0	0.0	0.0	0.0
07/1991	0.0	0.0	0.0	0.0
08/1991	0.0	0.0	0.0	0.0
09/1991	0.0	0.0	0.0	0.0
10/1991	8.0	23.7	7.7	22.7
11/1991	87.5	54.6	51.0	56.6
12/1991	293.5	246.2	97.9	241.7
01/1991	154.7	100.2	26.0	131.3
02/1991	104.5	72.2	49.7	103.8
03/1991	154.2	85.7	75.8	125.0
04/1991	2.7	19.7	5.6	12.3
05/1991	0.0	0.0	0.0	0.0
Sub-Total	805.1	602.3	313.7	693.4
Mean				
Total	1,643.9	1,343.9	817.5	1,608.1

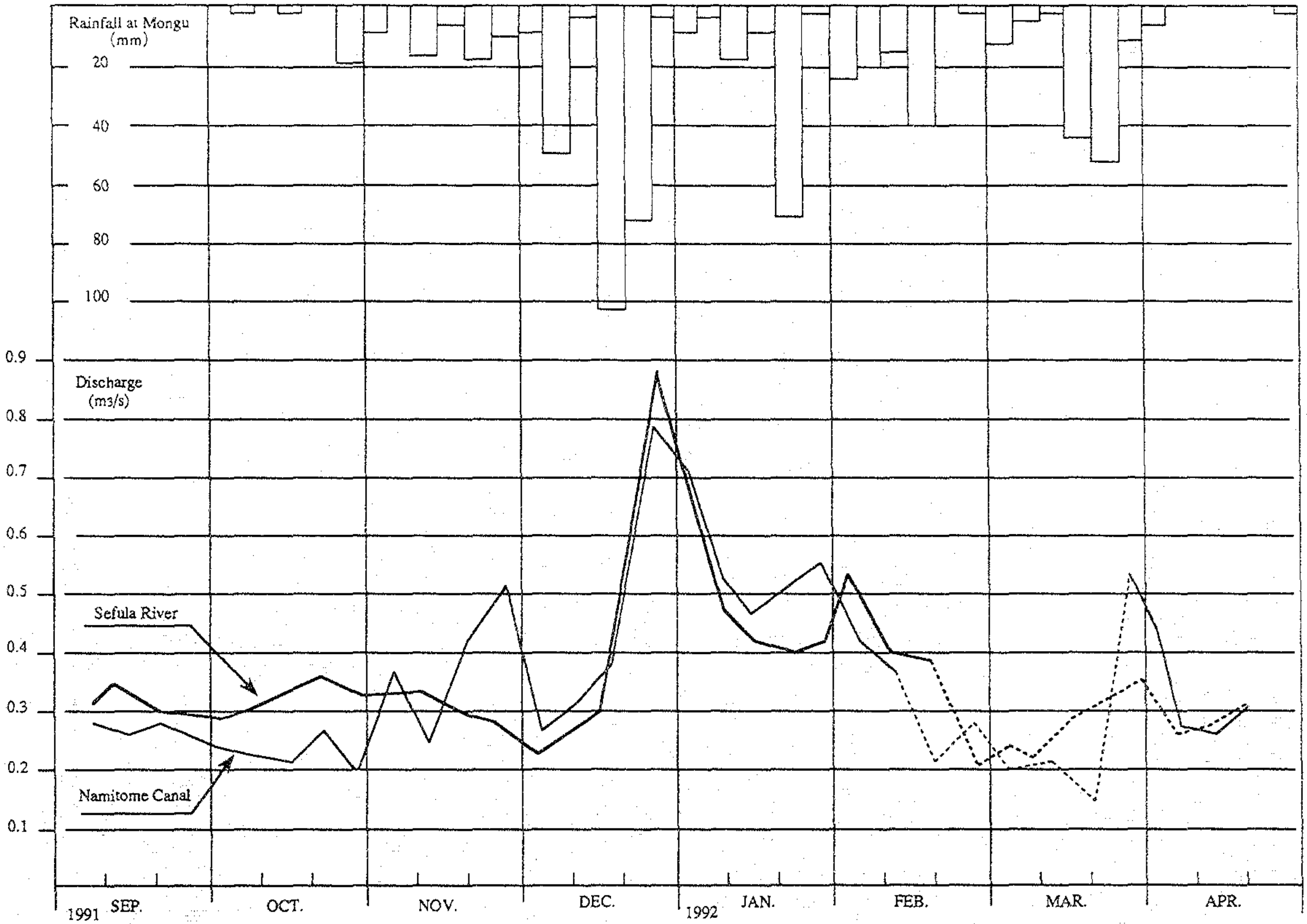
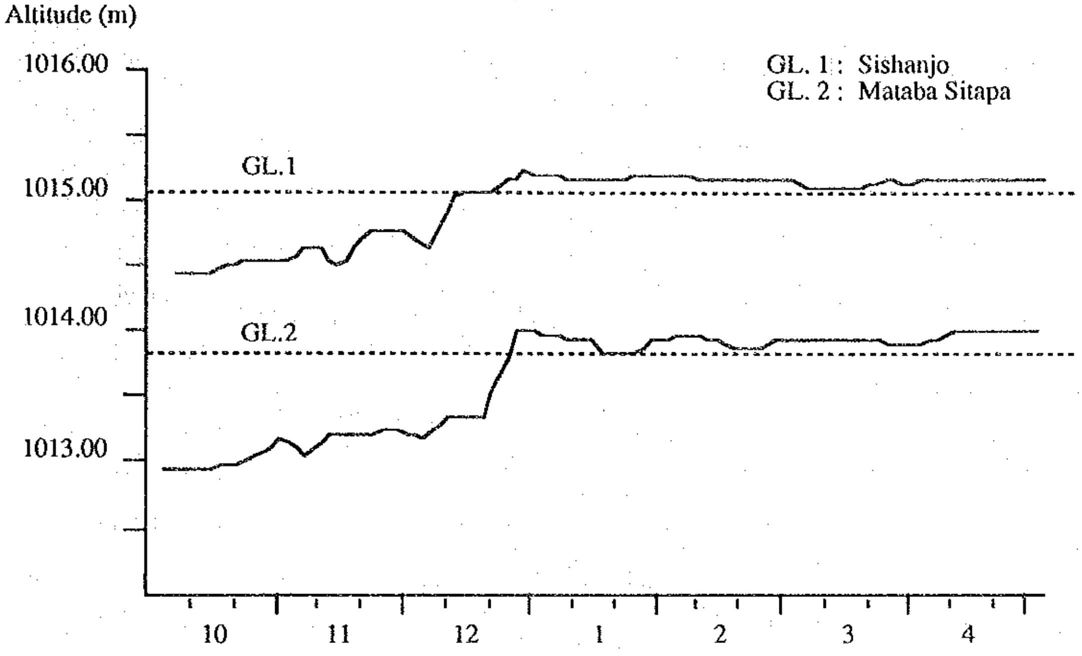
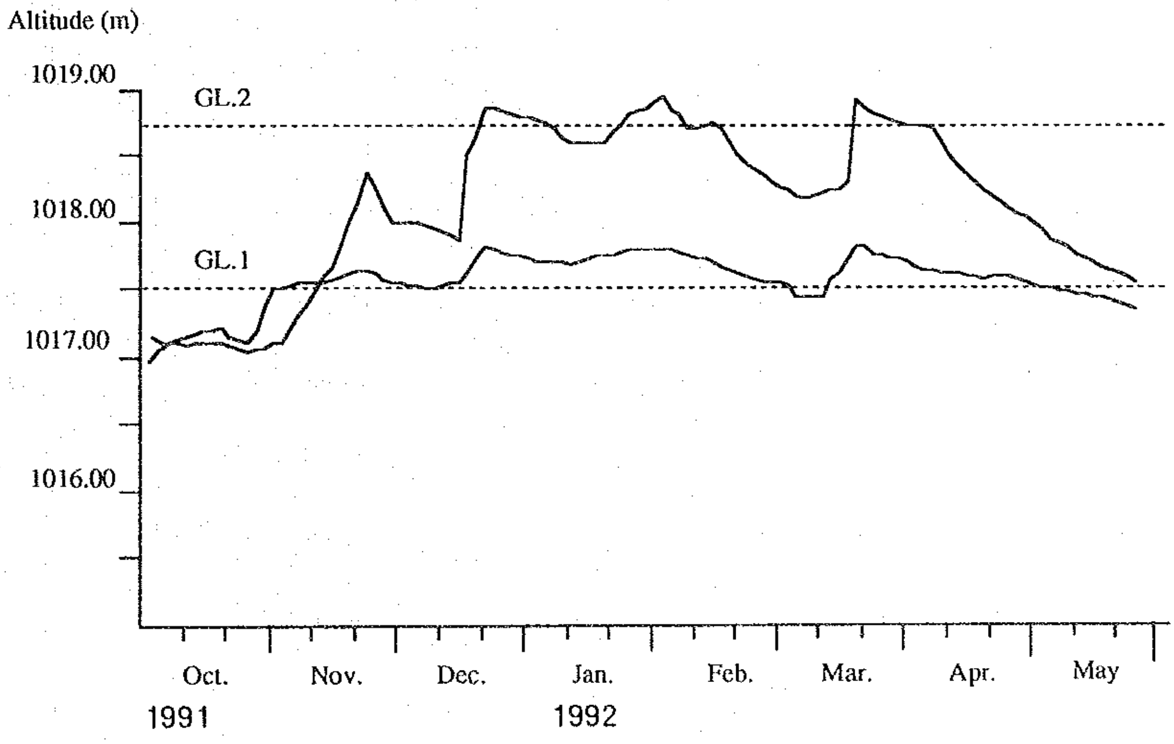


Figure III.1.1 Water Discharge Fluctuations of Sefula River and Namitome Canal
(Sep. 1991 - Apr. 1992)



(A) Sefula Area



(B) Limulunga Area

Figure III. 1. 2 Water Level Fluctuations in the Model Areas

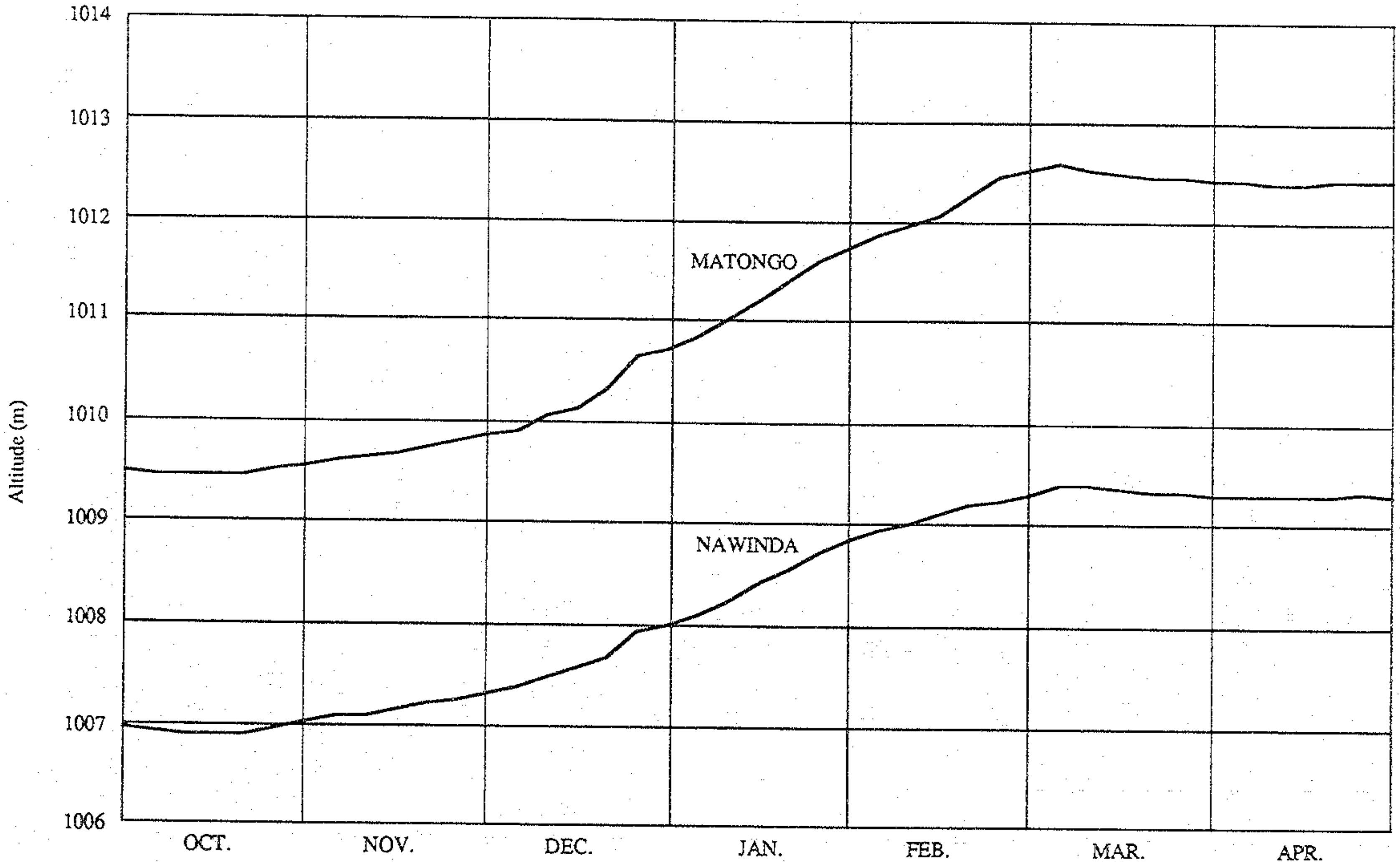


Figure III. 1. 3 Comparison of Water Level Fluctuations at Two Locations of Little Zambezi (Oct. 1991 - May. 1992)

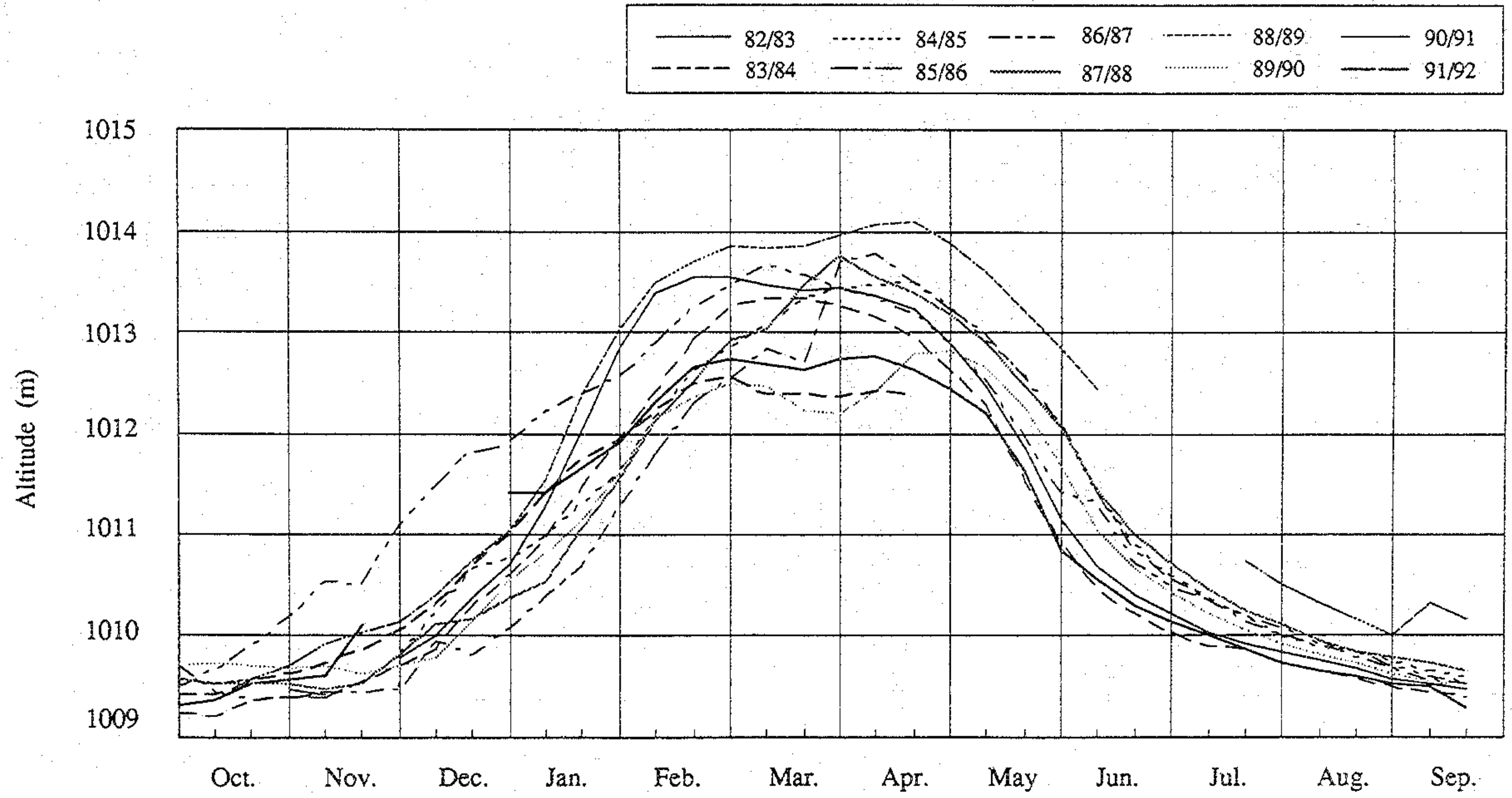


Figure III.1.4 Water Level Fluctuations of Little Zambezi at Matongo

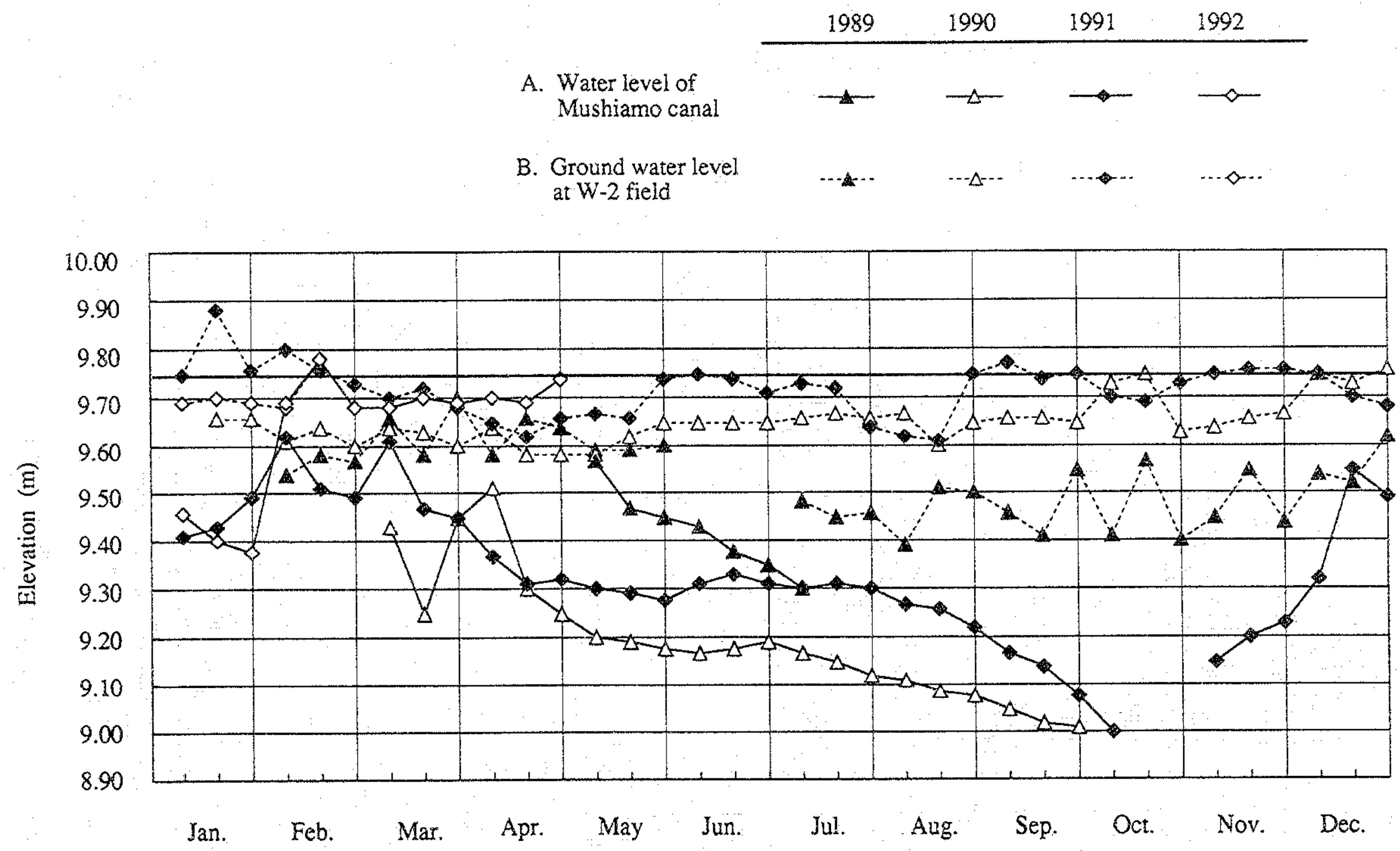


Figure III.1.5 Water Level Fluctuations at Namushakende AVS - Farm

Feb. 1989 ~ Apr. 1992

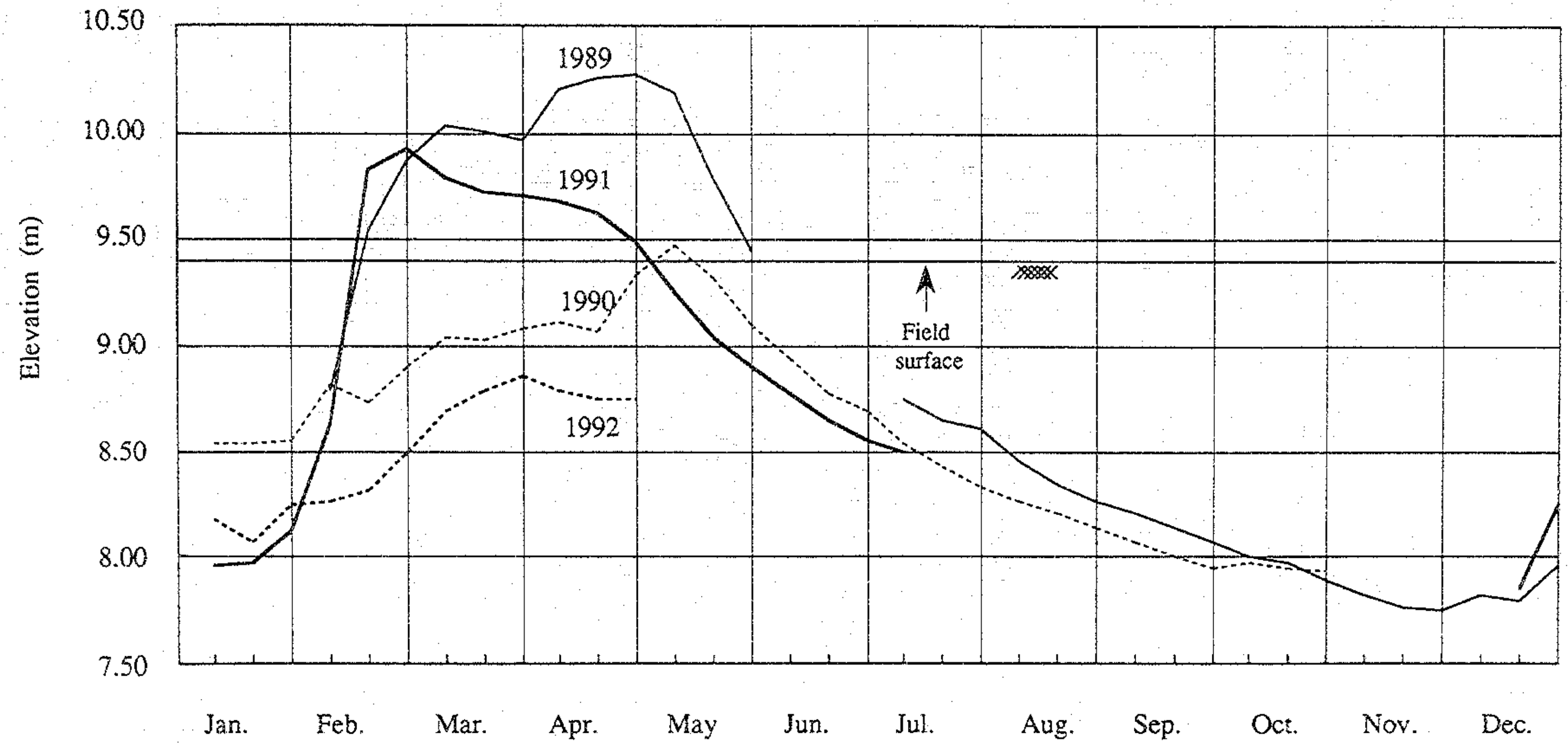


Figure III.1.6 Water Level Fluctuations at Lealui AVS - Farm

Feb. 1989 ~ Apr. 1992

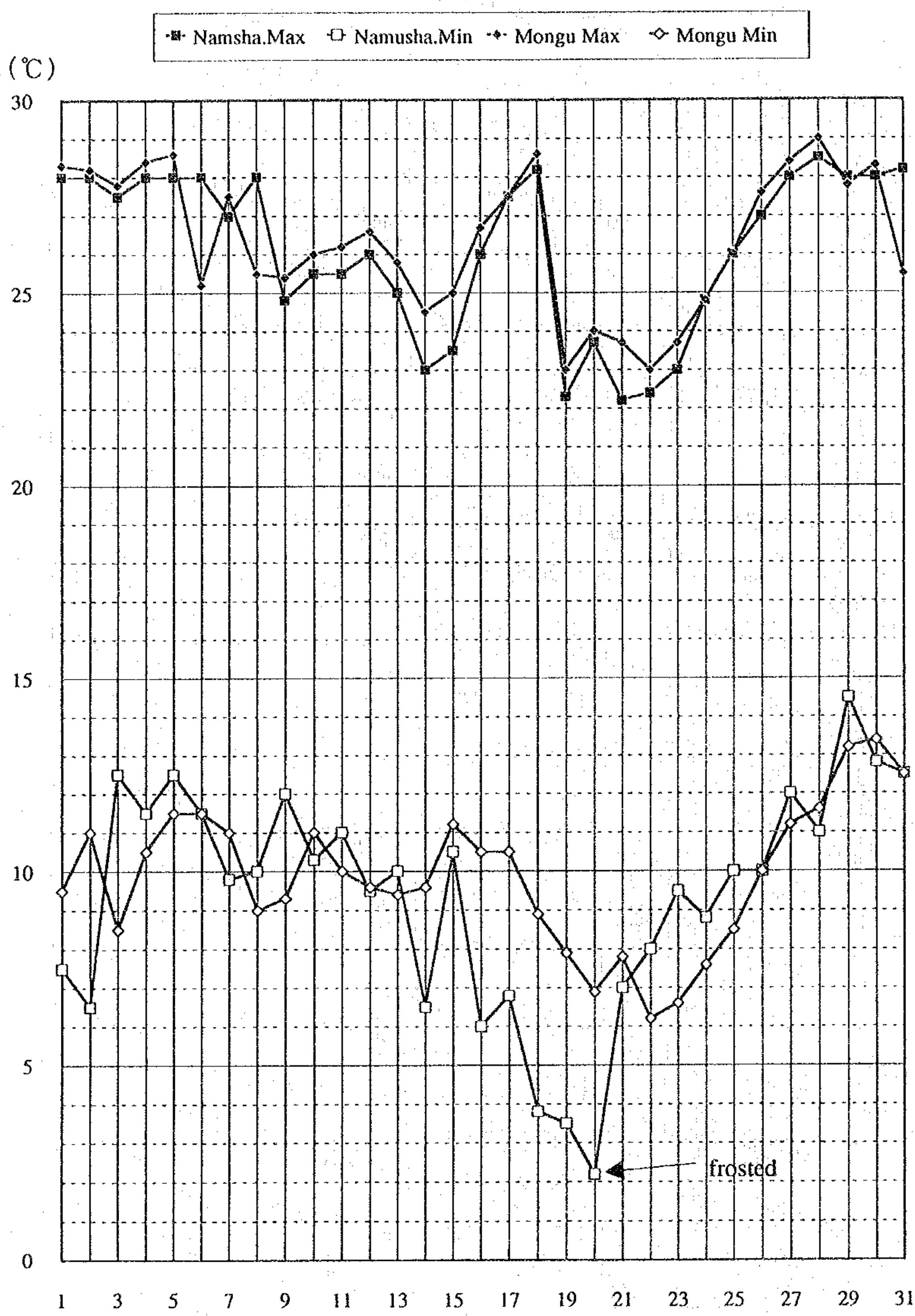


Figure III.1.7 Max. and Min. Temperature at Namushakende and Mongu (Jul./1989)

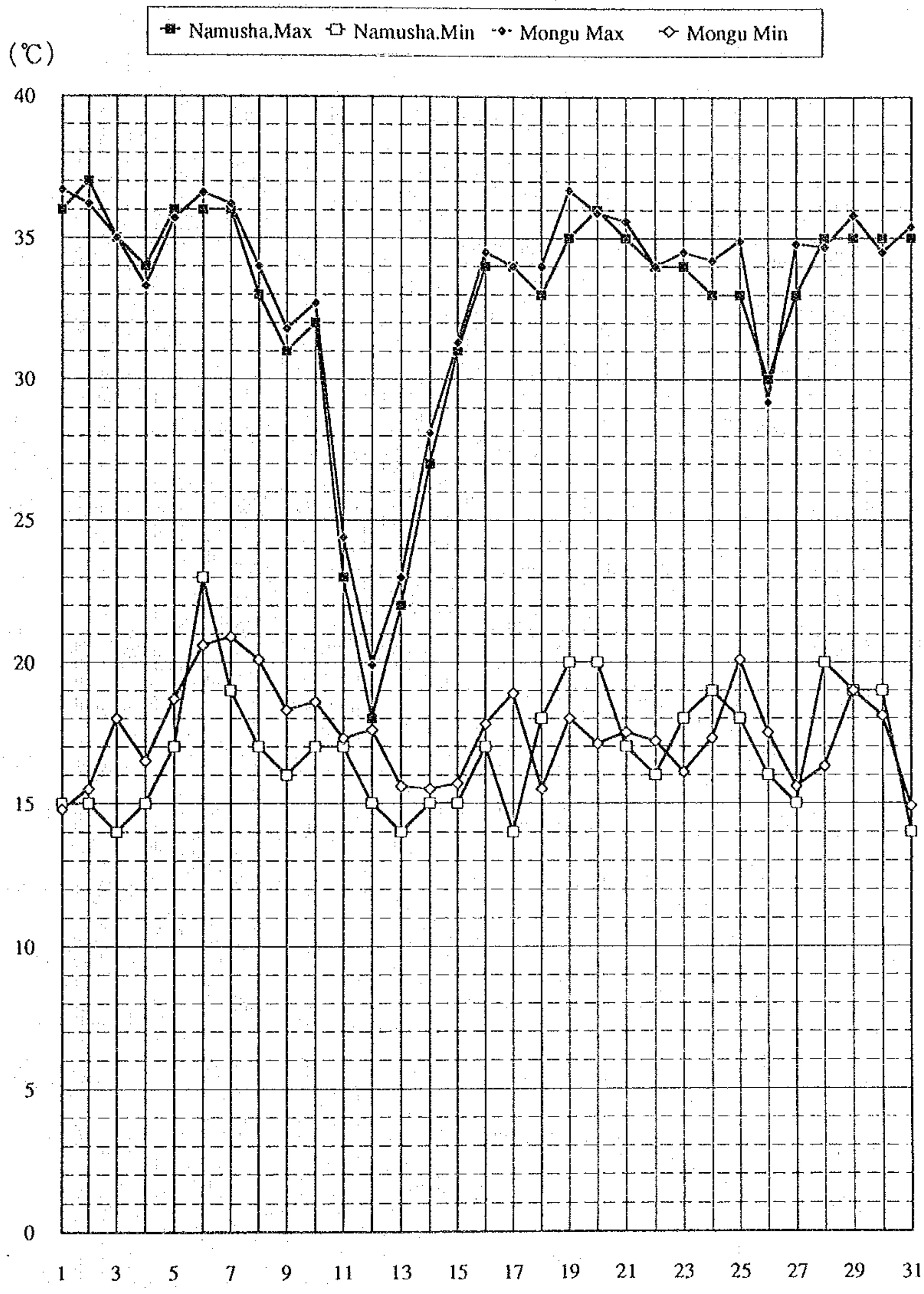


Figure III.1.8 Max. and Min. Temperature at Namushakende and Mongu (Oct./1989)

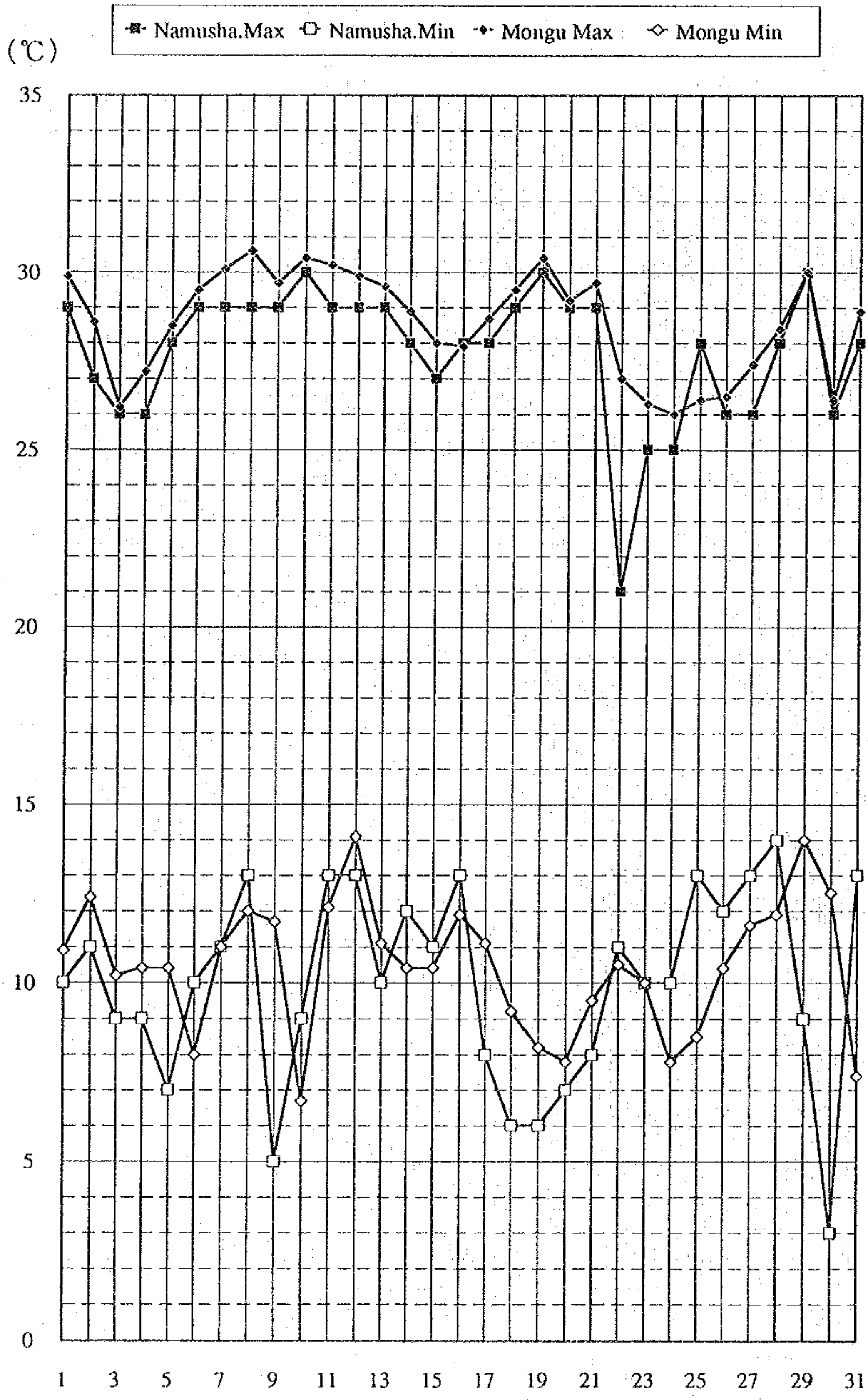


Figure III.1.9 Max. and Min. Temperature at Namushakende and Mongu (Jul./1990)

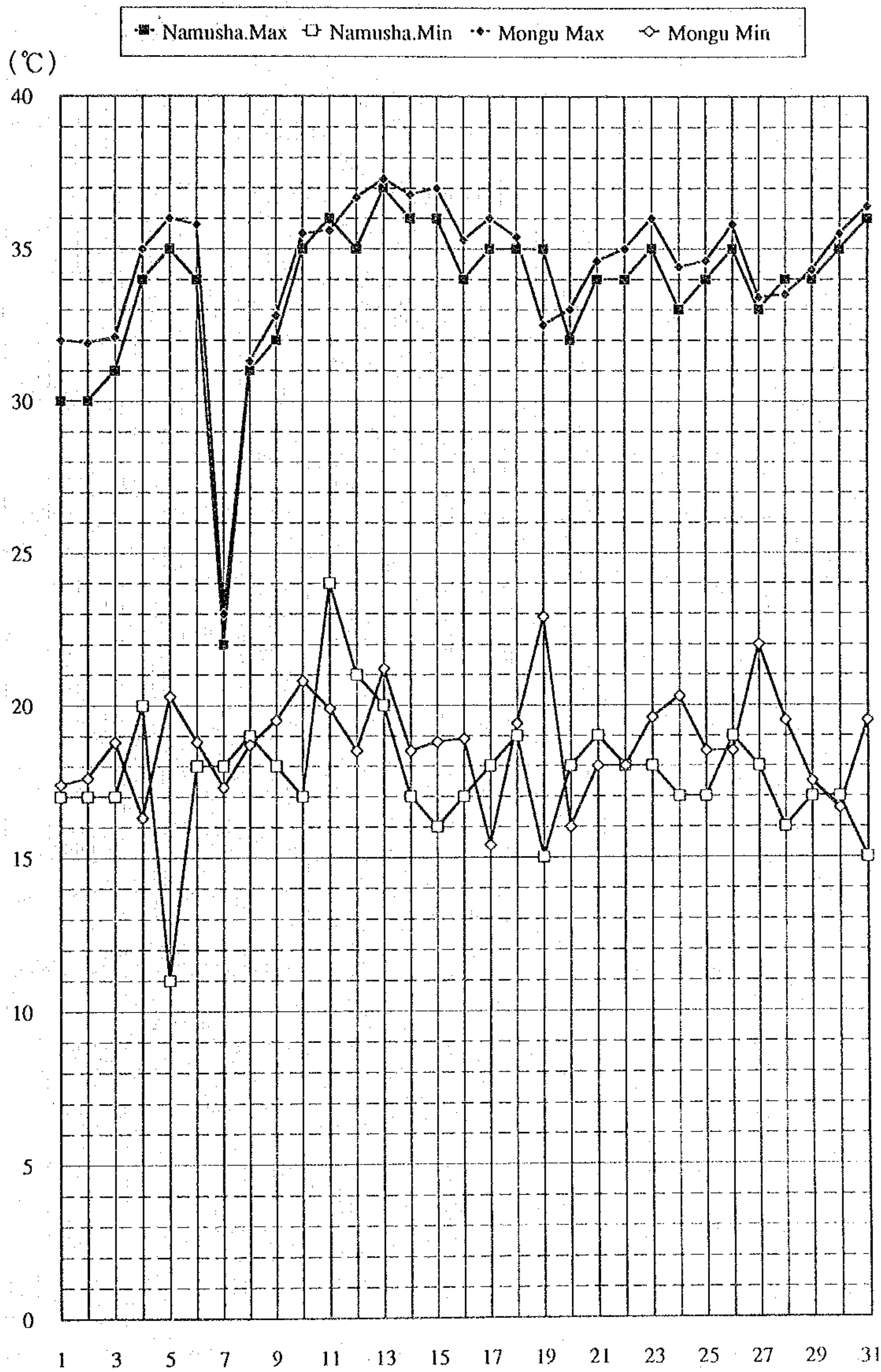


Figure III.1.10 Max. and Min. Temperature at Namushakende and Mongu (Oct./1990)

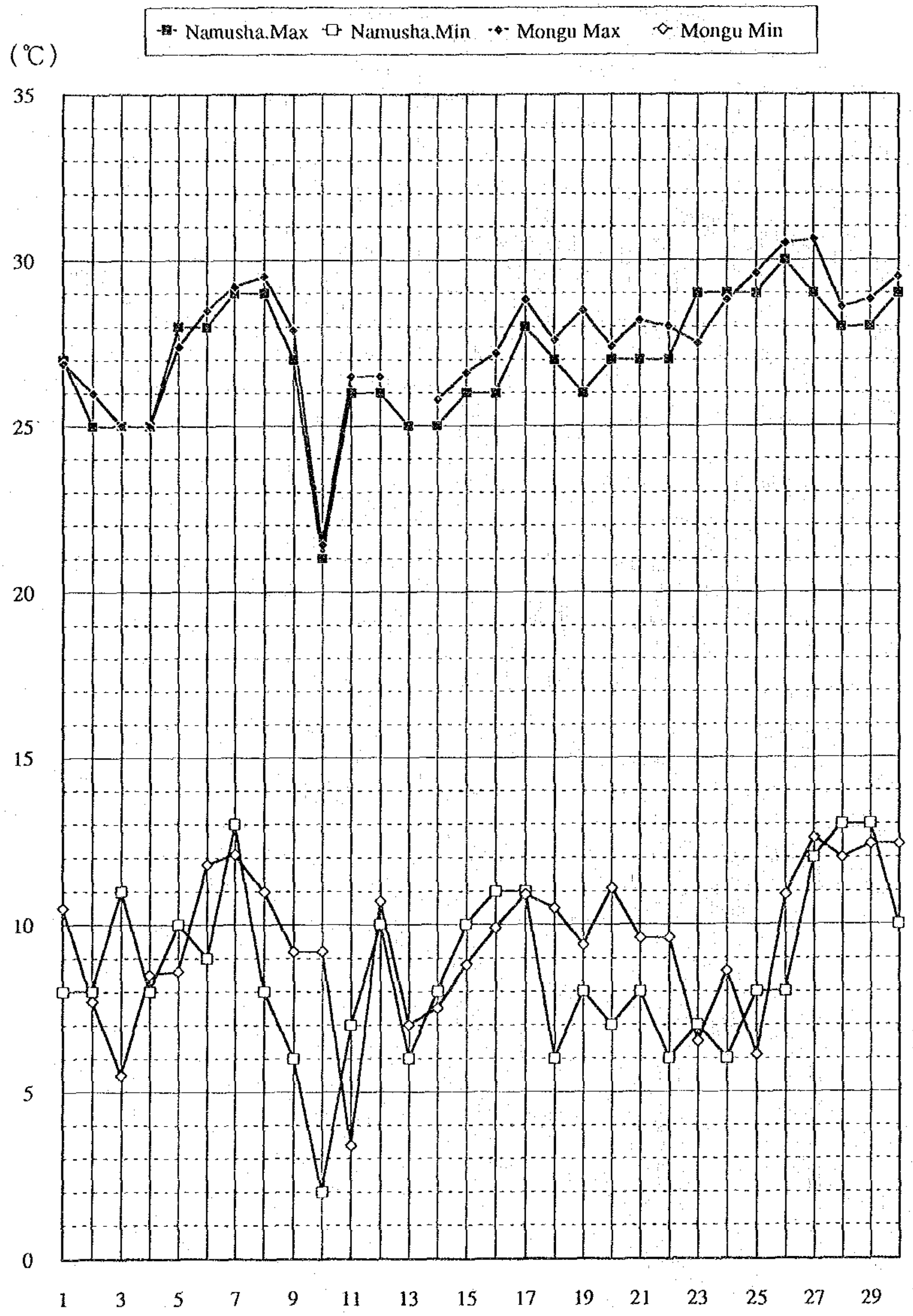


Figure III.1.11 Max. and Min. Temperature at Namushakende and Mongu (Jun./1991)

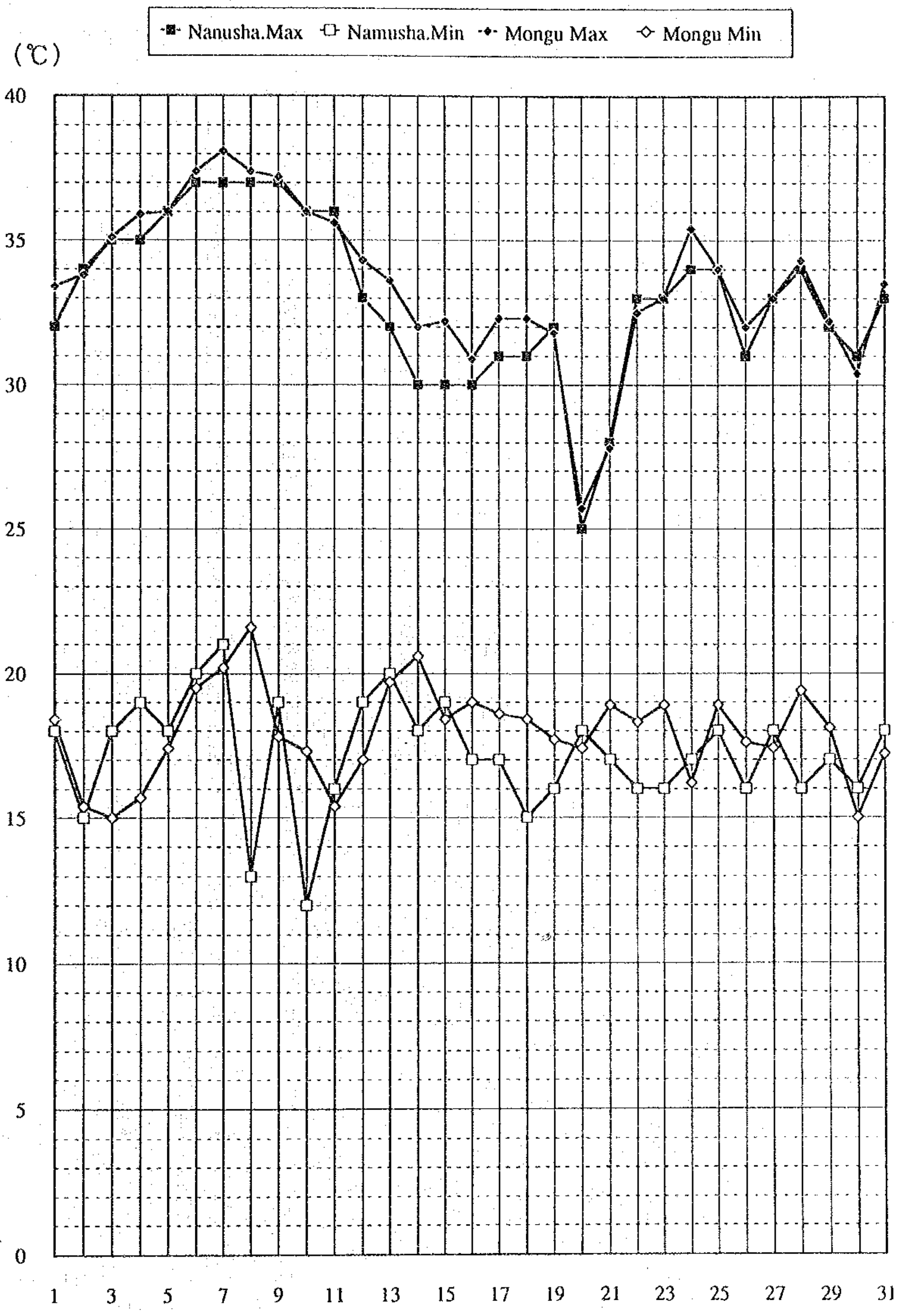


Figure III.1.12 Max. and Min. Temperature at Namushakende and Mongu (Oct./1991)

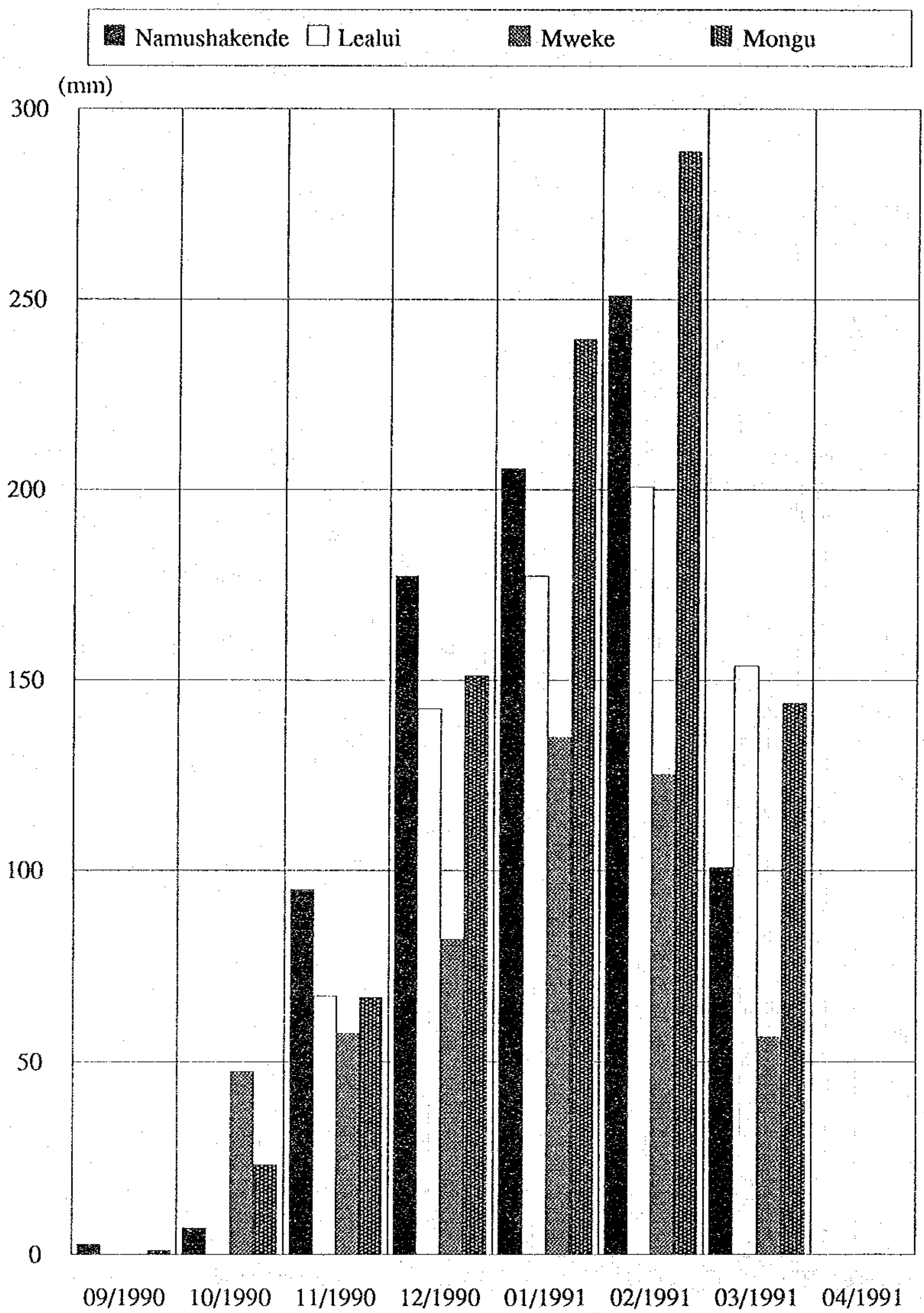


Figure III.1.13 Monthly Rainfall Comparative Graph for 1990/1991

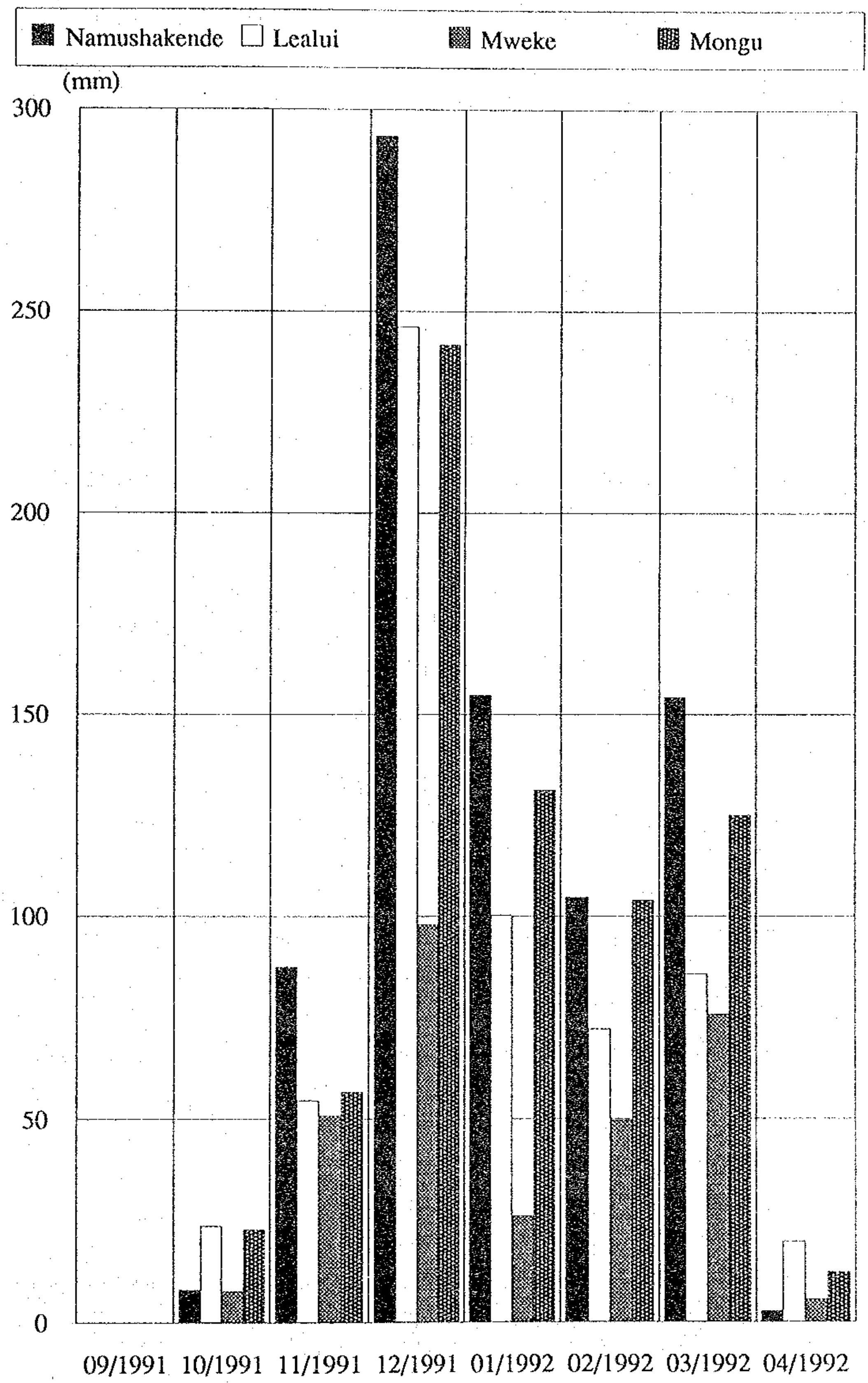


Figure III.1.14 Monthly Rainfall Comparative Graph for 1991/1992

III.2 Irrigation and Water Management Guideline

III.2.1 Scope of Application and Prerequisite for the Guideline

(1) Frequency and return period

Thirteen years of records of annual rainfall at Mongu Meteorological Station (1979 ~ 1991) was examined to determine the frequency a specified occurrence is not exceeded.

Various formula have been developed and one of the most common is the Hazen formula. In general, if the record is rearranged so that the smallest event is ranked number 1, the second smallest number 2 and so on, then the frequency of any event using the formula is given by

$$F = (2m-1)/2n$$

where F: frequency, m: rank and n: total number of years.

The return period, or the recurrence interval is the reciprocal of the frequency [Tr: 2n/(2m-1)]. The recurrence interval of a particular event whether rainfall or flood is of obvious importance for design considerations. Large return period would be used for the design of structures where failure would result in excessive costs. In minor structures, however, where failure will result in only slight damage and where the cost of repair is minimal, a relatively short return period can be used.

For design purposes, a 3 to 5 year return period was used for the plain edge area, our area of concern. As shown in Table III.2.1, it corresponds to the event where 760.2 mm was recorded. This occurred in 1983.

(2) Meteorological data at Mongu meteorological station in the reference year for design, 1983.

Daily rainfall and other meteorological data at Mongu meteorological station in 1983 are shown in Tables III.2.2 ~ III.2.6.

(3) Evapotranspiration

The calculation results of the reference crop evapotranspiration for the reference year are shown in Table III.2.7.

III.2.2 On-farm Irrigation Plan

(1) Determination of irrigation method

Upland irrigation methods vary depending on specific purposes. Determination of methods should be made in due consideration of such conditions as natural, farming, water utilization and financial level of objective areas, as it is closely connected with on-farm water use, and moreover, it affects on-farm facility expenses and maintenance cost.

According to the results obtained from cylinder intake rate survey carried out at Namushakende AVS farm, basic intake rate is 4 mm - 21 mm/hr and soil intake rate is small, such as shown in Tables III.2.14 and III.2.15. Due to the fact that spray irrigation requires great expense for sprinklers and piping, and moreover, maintenance of such equipments is difficult in the said area, surface irrigation is an appropriate method in the flood plain edge area. Surface irrigation refers mainly to furrow irrigation and border irrigation. After due consideration of flow and groundwater level, furrow irrigation is selected for this plan.

Table III.2.14 Intake Rate at Namushakende AVS Farm

	1989	1990	1991
Initial Intake Rate	21.3 (mm/hr)	153.2 (mm/hr)	243.6 (mm/hr)
Basic Intake Rate	14.9 (mm/hr)	3.6 (mm/hr)	20.9 (mm/hr)

Table III.2.15 Determination of Irrigation Method by Intake Rate

Soil Permeability	Basic Intake Rate	Optimum Irrigation Method
High	More than 75 mm/hr	Spray Irrigation
Medium	50 ~ 75 mm/hr	Spray/Surface Irrigation
Low	Less than 50 mm/hr	Surface Irrigation

In practicing of furrow irrigation, appropriate furrow flow, furrow length, width and irrigation application time proportional to intake rate are determined so as to include an effective root zone of crops in the wet area produced after irrigation.

(2) Determination of furrow flow rate and furrow intake rate

As basic data for furrow irrigation plan, furrow flow rate and intake rate should be determined through actual measurement.

1) Furrow flow rate

Furrow flow rate refers to the speed of water at the end of the furrow. It is subjected to the influence of slope, shape, amount of water supply and intake rate. It also depends on the maintenance conditions of the furrow.

Achievable distance of furrow flow rate (L) and time are shown as follows:

$$t = \alpha \cdot L^{\beta}$$

where, α and β are furrow flow rate constants

2) Furrow intake rate

Mean furrow intake rate is found through supplying an appropriate amount of water into a furrow and measuring the difference between inflow and outflow. As the measurement is conducted under the same conditions as actual irrigation, the most appropriate value is obtained.

Furrow intake rate refers to the amount of water per unit area and time taken into a furrow.

Intake rate per farm is expressed as follows:

$$I = \frac{60 \cdot K'}{L \cdot B} \cdot T^{n} = K \cdot T^{n} \text{ (mm/hr)}$$

where, K and n are furrow intake rate constants

$$K = \frac{60}{L \cdot B} \cdot K'$$

L is furrow length, B is furrow width

The results obtained from actual measurement in section 1) and 2) above performed in Namushakende AVS farm are shown in Table III.2.4.2.

The test conditions include: furrow length 25 m; width 0.8 m; slope 1/250, 1/500; flow 0.25 l/s, 0.50 l/s and 0.67 l/s.

(3) Determination of irrigation time

The time required for irrigation is determined using such actually measured data as furrow length, amount of irrigation water, furrow intake rate and furrow flow rate. The procedure is shown below.

When furrow irrigation is carried out with a length of L(m) and an irrigation depth of D (mm), T is found as follows:

$$T_f = T + t = \left[\frac{60 \cdot D \cdot (n+1)}{K}\right]^{\frac{1}{n+1}} + \alpha \cdot L^{\beta}$$

where, T_f: the time required for supplying a given amount of water into a furrow of length L(m), taking a loss in the deep layers into consideration.

T: the time required for allowing a required irrigation depth (d) (mm) at a certain spot in a furrow.

t: the time required for furrow flow to reach a certain spot in a furrow.

The relationship between accumulated intake amount (D) required to reach the point L (end) and the time required for intake (T) is obtained by the integration of the aforementioned furrow intake rate $I = K \cdot T^n$

To be more specific,

$$D = \frac{I}{60} \int I \cdot dT = \frac{K}{60 \cdot (n+1)} \cdot T^{n+1} \qquad \text{(mm)}$$

Accordingly, the time required to allow the intake of the required irrigation water requirement is:

$$T = \left[\frac{60 \cdot D \cdot (n+1)}{K}\right]^{\frac{1}{n+1}} \qquad \text{(min)}$$

The obtained time covers the amount of time required after furrow flow has reached an end, therefore, the total required time (T_f) is found by adding furrow flow arrival time $t = \alpha \cdot L^{\beta}$.

The required time for irrigation, when the amount of irrigation water requirement is 59.4 mm (TRAM), is shown in Table III.2.4.

(4) Determination of furrow length and width

The maximum allowable furrow length refers to the possible length reached by furrow flow without soil erosion and significant loss in the deep layers. The higher furrow flow becomes and the smaller intake rate becomes, the longer the maximum allowable length becomes.

In order to enhance labor efficiency of water allocation at a time, the longest possible length is desired. However, an application efficiency for irrigation limits the length. Figure III.2.1 indicates a relation between the time elapsed and an arrival time of furrow flow when a various amount of water is supplied into the furrow with certain soil texture and slope assuming that a flow amount exceeding b(l/min) causes erosion. The max. allowable length L_{max}, when m = 3 (or t = T/3), adopted with regard to the application rate which will be mentioned later, is shown in Figure III.2.1.

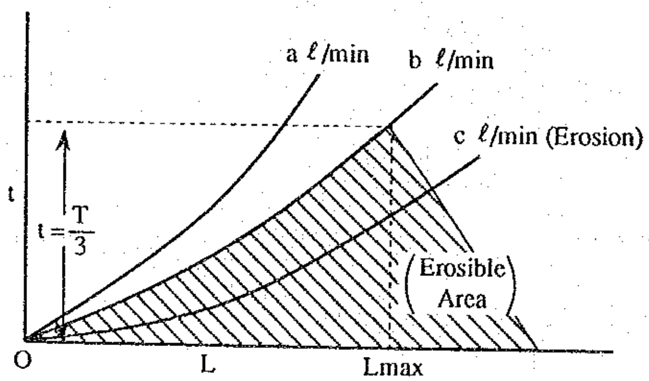


Figure III.2.1 The Maximum Allowable Furrow Length

The experimental results obtained from AVS shows, when slope is 1/250 and amount is 0.67 l/s, a partial loss of soil of fine texture is observed. It also indicates that when slope is 1/250, erosion most likely occurs with a flow exceeding 0.67 l/s. After due consideration of such conditions mentioned above and using the aforementioned method, the max. allowable length, L_{max} = 22 m, was obtained.

Considering that the actual critical velocity is higher than 0.67 l/s, the optimum furrow length is determined as 25 m.

- Determination of furrow width

In the practice of furrow irrigation, the cross-sectional distribution of water after irrigation must be considered. To be more specific, furrow width should be determined so as to allow irrigation water penetrate edges to include an effective root zone in this wet area.

When water is supplied into a furrow composed of evenly textured soil, water often indicates a horizontal movement in case of clay loan. Meanwhile, in case of sandy soil, water mainly percolates. Consequently, in case of sandy soil, wider width is not appropriate and, moreover, the amount of water supplied to the surface at a time should be limited to prevent the loss in the deep sublayer. For the above reasons, furrow irrigation on sandy soil is not desirable.

An example of maximum width obtained from experiments is shown in Figure III.2.2.

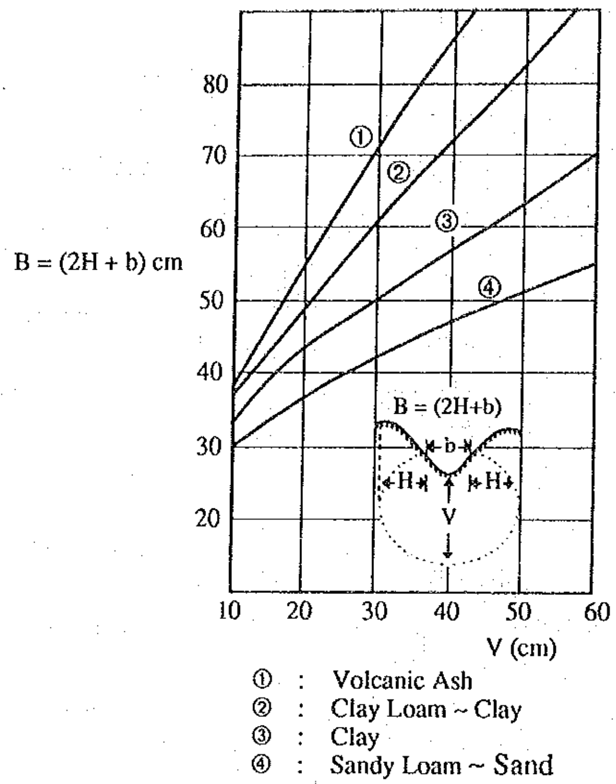


Figure III.2.2 An Example of Maximum Furrow Width

As a result of observation performed at Namushakende AVS farm (using maize), furrow width was set at 80 cm, as an effective root zone was adequately included in the wet area. Along with the above experiment, cultivation tests of maize were also conducted to find the optimum furrow height. As a result, considering the balance between labor and yield, the optimum height is selected as 15 cm.

(5) Irrigation efficiency

A concept of irrigation efficiency in a farm includes application efficiency which refers to the amount of irrigation water retained in an effective root zone and eventually used by the crops. As for furrow irrigation, a plan should be established so as to ensure a rate of 70% or higher. Assuming that irrigation water applied into an furrow has reached an end after t minutes, at the moment water start to percolate downward through soil at that end, the beginning end, has been under percolation for t minutes (Figure III.2.3.).

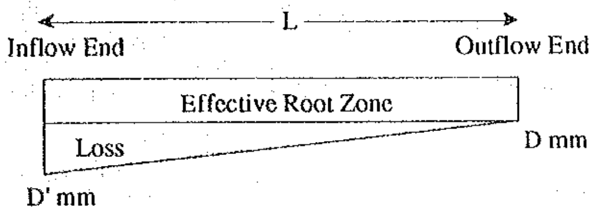


Figure III.2.3 Loss Amount of Furrow Irrigation

As can be seen in Figure III.2.3, assuming that it requires T minutes to attain a intake water depth of D (mm) at an end, penetration time at a beginning end is (T + t) minutes. Where, intake water amount D' is given as follows:

$$D' = \frac{K}{60 \cdot (n+1)} \cdot (T+t)^{n+1} \qquad \text{(mm)}$$

Consequently, when a farm is horizontal and thus the prevention of overflow loss by closing a downstream end is possible, application rate E is shown as follows:

$$Ea = \frac{D}{\frac{1}{2} \cdot (D'+D)} \times 100 = \frac{200 \cdot D}{\frac{K}{60 \cdot (n+1)} \cdot (T+\alpha \cdot L^{\beta})^{n+1} + D} \qquad (\%)$$

In furrow irrigation, loss in the deep layers(W_L) refers to the amount of water penetrated from the effective root zone downward.

$$W_L = 1 - \frac{Ea}{100}$$

Generally, in consideration of actual furrow irrigation work, appropriate measures are taken so as to allow irrigation water to reach a furrow end within T/m hrs. (Where t = T/m). The value m depends on the soil intake constants K, n.

when, as to $D = \frac{K}{60 \cdot (n+1)} \cdot T^{n+1}$, use C for $\frac{K}{60 \cdot (n+1)}$

D is shown as below:

$$D = C \cdot T^{n+1}$$

As can be seen in Figure III.2.4, an intake depth after t minutes is D_1 at point A and zero at point B. After 2t minutes, it becomes D_2 at point A and D_1 at point B. Consequently, the distribution of intake water after mt minutes becomes D_m and

D_{m-1} at point A and B respectively. After (m+1) t minutes, it becomes D_{m+1} and D_m at point A and B respectively.

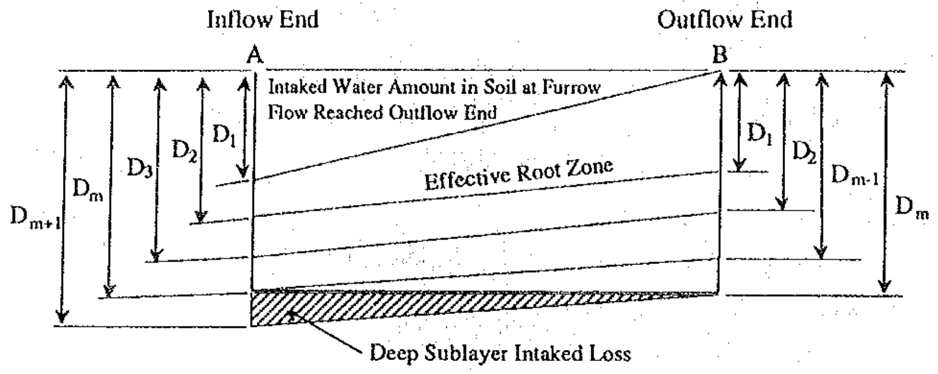


Figure III.2.4 Application Efficiency of Furrow Irrigation

Consequently, application rate (E_a) is as follows:

$$E_a = \frac{D_m}{\frac{1}{2} \cdot (D_{m+1} + D_m)} \times 100 = \frac{2 \cdot m^{n+1}}{(m+1)^{n+1} + m^{n+1}} \times 100 \qquad (\%)$$

Figure III.2.5 Illustrates the above.

As *m* becomes larger, the flow becomes larger, which likely causes erosion. *m* should desirably be as small as of between 3 and 4.

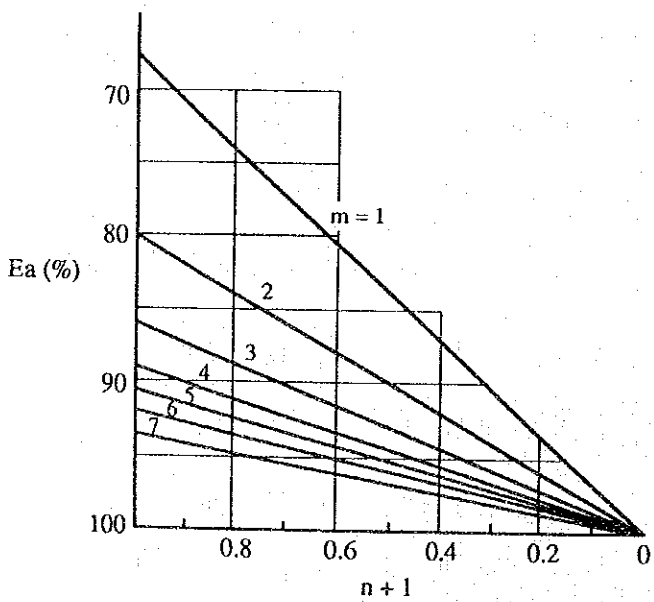


Figure III.2.5 Application Efficiency Nomograph

With the usual field slopes seen, cutting intake amount according to a decline of intake rate enables the prevention of overflow loss at a downstream end, which, however, is difficult to attain.

Consequently, there is no other option than finding experimentally overflow loss which meets the specific land conditions, and adopting an amount of water including a loss amount in deep layers in the calculation application efficiency. As long as the farm mentioned in this plant is concerned, closing a downstream end is possible. Therefore, application efficiency is determined as follows:

$$Ea = \frac{200 \cdot D}{\frac{K}{60 \cdot (n+1)} \cdot (T+\alpha \cdot L^{\beta})^{n+1} + D}$$

$$= \frac{200 \times 59.4}{\frac{101.7}{60 \times 1.756} \cdot (10.9 + 0.07 \times 25^{1.28})^{1.756} + 59.4}$$

$$= \frac{11,880}{174.3} = 68.2 \fallingdotseq 70\%$$

III.2.3 Paddy Rice Irrigation Trial

(1) Objectives

To investigate adequate irrigation method for the Sishanjo area in the flood plain edge.

(2) Results and discussions

Generally, growth in each plot was good right from the beginning. But after one month, a little change was seen in the color of leaves which turned somewhat yellow. Especially this trend was more remarkable in the continuous irrigation plots. Growth difference among the irrigation plots and the rain fed plots had become obvious since that period. After two months, the outbreak of brown spot was seen in every plot but general growth was not affected. Flowering occured in the middle of April but in the 7 days intermittent irrigation plots, it was observed a week later.

Yield survey was carried out on the 19th of May at 101 days after transplanting. The results are shown in Table III.2.9. The 7 days intermittent irrigation plot had the best yield at 4.2 ton/ha and other plot's yields are as follows.

3.4 ton/ha for the 4 days intermittent irrigation plots
3.4 ton/ha for the continuous irrigation plots
2.9 ton/ha for the rain fed plots
(The rainfed plots/were benefiting from the seepage water out of the secondary irrigation canal.)

From the above mentioned results, the effect of irrigation was clear. It is considered that the decrease in nutrient loss and the mitigation of irrigation water acidity related with the 7 days intermittent irrigation plot accounted for the better yield recorded in that plot. Therefore, the 7 days intermittent irrigation which showed high yield and advantageous irrigation water saving can be recommended as adequate irrigation method for the flood plain edge.

The water requirements recorded for the irrigated plots in this trial, were respectively 7.3mm/day (February), 8.4 mm/day (March) and 10.6 mm/day (April) as monthly average water requirements .

III.2.4 Intake Rate Measurement

(1) Objectives

Intake rate is measured to investigate the change of soil permeability with respect to time in a field where crops were cultivated continuously.

(2) Definition of intake rate

1) Accumulated depth

Accumulated depth (D) is related to elapsed time (T) according to the following formula:

$$D = C \cdot T^n$$

where, D : accumulated infiltration depth (mm)
T : elapsed time after supplying water (min)
C : constant (when T=1, C=D)
n : constant (slope of the line)

This relationship can be verified by plotting the observed data on a log-log paper.

2) Intake rate (I)

The intake rate is the differential of accumulated infiltration depth with respect to time ($D = C \cdot T^n$).

$$I = 60 \cdot C \cdot n \cdot T^{n-1}$$

where, I : intake rate (mm/hr)
T : elapsed time (min)
n : constant (slope of the line)

3) Basic intake rate (Ib)

The intake rate gradually decreases with respected to time after the beginning of irrigation, then finally stabilizes at a constant value at some time T. The basic intake rate is defined thin as the intake rate at that time T and indicates the permeability of an unsaturated soil.

In general, the basic intake rate can be approximated defined as the value of the intake rate when the variation ratio of the infiltration curve goes down to 10 percent. At that time, the elapsed time (Tb) can be estimated as follows:

$$Ib = 60 \cdot C \cdot n \cdot Tb^{n-1} \text{ (mm/hr)}$$

When the basic intake rate is estimated from the measured infiltration curve, the intake rate corresponding to the elapsed time (T = 600 (1-n)) shall be read from the graph.

(3) Results

The results are shown in Table III.2.10 and Figures III.2.6 - III.2.9.

III.2.5 Interrow Spacing Examination Trial

(1) Objectives

To investigate adequate interrow spacing from an irrigation water saving point of view in sandy soil located at the central part of the flood plain.

(2) Results and discussions

Germination was satisfactory in all plots a week after sowing. Leaf yellowing occurred at the beginning of October during the middle growing stage of growth but the crop recovered following the application of urea as a top dressing. The difference in growth was apparent from the middle stage of growth and became more obvious in the later stage. Maturation was reached early December, and yield survey was carried out during that month.

The results of the yield survey are shown in the Table III.2.11 and can be summarized as follows. Average dried grain yield for the 80 cm, 65 cm and 50 cm interrow spacing were respectively 45.0 kg, 39.3 kg and 30.3 kg per stock. The unit yields which were converted from the average dried grain yields were 1,828 kg/ha (80 cm), 1,965 kg/ha (65 cm) and 1970 kg/ha (50 cm). Consequently the difference between each plot is small and the effect of interrow spacing on water amount is not clear. However, adequate interrow spacing is considered to be the 80 cm because in case of 50 cm interrow spacing, farming work is not easy and the probability of occurrence of disease and insect damage is high.