II. Farming Operation

1. Soil Pulverization and Germination of Uplnd Crops

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It is extremely difficult to pulverize heavy clay soils of paddy fileds well enough to ensure good germination of seeds when upland crops are grown in dry season. The following two experiments were undertaken to study proper land preparation for growing upland cops.

1) Relationship between size of soil clods and germination of upland crops (1975)

The experiment was conducted to obtain the fundamental information about the size of soil clods required for good germination of upland crops.

Materials and method

Wooden frames containing soil clods of different size were prepared for seed beds to examine the germination and initial growth of crops.

Treatment:

Test crops:	Sorghum (representing the crops of small size seed)	(S_1)
	Maize (representing the crops of large size seed)	(S_2)
Size of clod:	< 2 cm	(C_1)
	2 — 3 cm	(C_2)
	3 — 4 cm	(C_3)
	> 4 cm	(C_4)
Depth of seeding:	2 cm	(D_1)
	4 cm	(D_2)
Irrigation method:	Irrigated from the bottom (similarly as furrow irrigation	(I_1)
	Irrigated from the top (similarly as rainfall	(I_2)

Replication: 2 times
Size of wooden frame: 45 cm × 45 cm × D. 14 cm
Seeding: 24 March, 1975
Growth check of seedlings: 3 April, 1975

Results

The emergence and growth of seedlings are shown in Fig. 1-1 and 1-2; Table 1-1 shows the F value as the result of statistical analysis on those data.

The percentage of seedling emergence was high as soil clods were fine. Especially in case of small size seed such as sorghum, emergence was obviously depressed in the seed bed containing large clods. Fine clods of soil induced rapid and uniform emergence as

indicated by less average number of days for emergence and less number of days for 90% emergence of whole emerged seedlings.

2) Effects of farming operation of preceding rice crop on efficiency of land preparation and growth of suceeding upland crops (1974 — 1975)

The experiment was conducted to clarify the effect of farming operation in rice cultivation such as puddling and application of compost to soil, on the efficiency of land preparation and the growth of succeeding upland crops with reference to soil moisture conditions at tilling time.

Materials and method

Treatment:

Puddling for rice cultivation	no puddling	(P_1)
	light puddling	(P_2)
	heavy puddling	(P_3)
Compost application for rice cultivation	0 tons/ha	(C_1)
	5 tons/ha	(C_2)
	20 tons/ha	(C_3)
Soil moisture content when the field was tilled for succeding upland crops	low	(M_1)
	moderate	(M_2)
	high	(M_3)

Layout: A split plot design was applied to dispose M treatment as a main plot, P and C treatments as sub-plots with one replication. The size of sub-plot was 11 m × 24 m = 264 m^2. L 27 (3^{13}) table was employed for a statistical analysis.

Cultivation of rice:

Variety: RD 1

Transplating: 24 July, 1974 (20 day seedling)

Fertilizer: N: 40 Kg/ha (1/2 for basal and 1/2 for top dressing)

P_2O_5: 25 kg/ha

K_2O: 12.5 kg/ha

Spacing: 25 cm × 25 cm

Harvesting: 11 November, 1974

Tilling: Tillings were made 3 times in each plot with a rotary tiller (Howard Rotavator) attached to a tractor (MF 178), at different dates varied according to soil moisture treatments as shown in Fig. 1-3.

Germination test: Wooden frames (45 cm × 45 cm × D. 14 cm) which were filled up with soils taken from each plot after tilling were prepared for seed beds. Maize seeds were sown on the beds with a rate of 50 seeds per frame on 13 February, 1975.

Cultivation of upland crops in the field: Nine crops such as maize, sorghum, rice, soybean, peanut, mungbean, cotton, sunflower and sesbania were seeded after third tilling, on December 19 in M_3 plot, February 11 in M_2 plot and March 17 in M_1 plot.

Results

1. Growth of rice.

   As shown in Table 1-2 and 1-3, any effect of puddling and compost application was not observed on the growth and yield of rice. However, puddling obviously affected the emergence and development of weeds (Table 1-4). Weed population

was evidently abundant in non-puddling plot (P_1) comparing with that in puddled plots (P_2 and P_3).

2. Soil physical properties (Table 1-5)

Both the hardness and bulk density of soil increased as the soil moisture was lost after harvest of rice. (Table 1-5). As for puddling treatment, the hardness and bulk density of soil were low in non-puddling plot (P_1) as compared with those in puddled plots (P_2 and P_3). However, the effect of compost application was not observed.

3. Soil pulverization

Fig. 1-3 shows the clod size distribution of soil after each tilling. Three levels of compost application were averaged in this figure since any significant difference was not seen among the treatments.

Soil moisture content at tilling time most evidently affected the extent of soil pulverization. Tilling at high soil moisture content (M_3 plot) resulted in a low proportion of small clods. The clods smaller than 2 cm in diameter accounted for only about 20% of the whole in that plot after second tilling while such small clods were about 30% in the plots (M_1 and M_2) where moisture content was low at tilling time. In M_1 and M_2 plots, weathering of soils caused by rainfall of mid-January brought about the sharp increase of the proportion of such small clods when third tilling was made.

Puddling gave rather negative effects on soil pulverization for succeeding upland crops; the proportion of the small clods in P_1 plot was somewhat higher than those in P_2 and P_3 plots.

4. Seedling emergence in the germination test.

These was found a significant correlation between the clod size distribution in terms of the percentage of soil clods smaller than 2 cm in diameter and the emergence of maize seedlings (Fig. 1-4). This shows that well pulverized soil induces high percentage of emergence as well as rapid and uniform emergence of maize seedlings.

5. Growth of upland crops in the field.

The growth of nine upland crops was evidently inferior in M_3 plot as compared with that in M_1 and M_2 plots (Table 1-6 and 7). The extent of soil pulverization which is dependent upon soil moisture content at tilling time was obviously one of the major causes to affect the plant growth. There was not seen a significant effect of puddling and compost application on the growth of the crops.

3. Discussion

The aforementioned results clarifyed that well pulverized soil was prerequisite to good germination and vigorous initial growth of upland crops. However, it was also noticed that pulverization of heavy clay soils was quite difficult in practice and that hard soil clods formulated through tilling and drying could hardly be broken down without weathering by rainfall.

Soil moisture content at tilling time is the critical factor to affect the extent of soil pulverization. However, the period of time appropriate for tilling in terms of soil moisture content is rather limited since paddy fields are to be tilled in the course of drying after rice harvest.

In this connection, trials are required to introduce a higher performance of tilling attachment or develop seeding methods ensuring good germination of seeds under the existing field conditions.

Table 1-1. F Value and its significance obtained from the analysis of variance on emergence and growth of seedlings with special reference to clod size of soil

Factor	Percentage of emergence	Rapidity of emergence	Uniformity of emergence	Plant hight	Number of leaves	Dry weight	
						Per frame	Per plant
		1)	1)				
S	>100***			>200***	8.51**	>400***	>700***
I	—	27.5***	25.9***	—	—	—	—
D	—	—	—	—	—	—	—
C	61.1***	53.7***	43.3***	21.31***	27.41***	43.58***	15.31***
C_1:$C_{2,3,4}$	>100***	>100***	>100***	26.24***	24.36***	>100***	38.94***
C_2:$C_{3,4}$	28.81***	41.1***	22.2***	21.57***	37.38***	17.56***	5.59*
C_3:C_4	11.59***	—	—	16.13***	20.50***	—	—
S × C	6.99**	—	—	15.52***	16.35***	14.51***	—

Remarks 1) S_1 (sorgham) plots were excluded from the analysis of variance.
2) Signs of ***, ** and * show a significance with 0.1%, 1%, and 5% level, respectively.
3) — indicates there is no significant effect.

Table 1-2. Growth of rice plant

Treatment		Plant height cm	Tiller No. /hill	Dry weight g/m²	LAI	RGR %/day	NAR g/m² day
			Aug. 26 — 27				
P_1	C_1	57.9	13.7	103	1.27		
	C_2	58.2	14.0	99	1.16		
	C_3	59.7	15.1	107	1.32		
P_2	C_1	58.6	13.6	96	1.10		
	C_2	59.8	14.5	95	1.09		
	C_3	57.7	13.8	99	1.16		
P_3	C_1	57.9	13.7	95	1.07		
	C_2	57.6	13.2	93	1.06		
	C_3	58.1	14.1	99	1.16		
			Sept. 10 — 11			Aug. 28 — Sept. 11	
P_1	C_1	63.2	13.0	250	1.21	6.3	7.4
	C_2	62.6	12.7	247	1.19	6.5	8.0
	C_3	65.4	13.7	266	1.20	6.5	7.7
P_2	C_1	63.6	14.0	253	1.22	6.9	8.5
	C_2	63.6	13.3	240	1.22	6.6	8.0
	C_3	62.7	13.5	232	1.24	6.0	7.0
P_3	C_1	63.4	13.6	246	1.26	6.8	8.3
	C_2	62.5	13.3	238	1.20	6.7	8.2
	C_3	62.6	13.6	255	1.18	6.8	8.3
			Oct. 1 — 2			Sept. 11 — Oct. 2	
P_1	C_1	87.9	11.6	525	1.83	3.6	8.9
	C_2	88.4	11.8	545	1.87	3.7	9.0
	C_3	90.2	12.3	560	1.92	3.5	8.9
P_2	C_1	87.7	11.9	541	1.84	3.6	8.7
	C_2	87.2	11.4	512	1.90	3.6	8.1
	C_3	87.1	12.2	540	1.90	4.0	9.0
P_3	C_1	86.9	12.1	546	1.90	3.8	8.7
	C_2	86.1	11.9	570	1.88	3.6	8.2
	C_3	86.0	12.1	527	1.91	3.5	8.4

Remarks LAI: Leaf Area Index
RGR: Relative growth Rate
NAR: Net Assimilation Rate

Table 1-3. Yield and yield componet of rice

Treatment		Yield	Yield component			
		Weight of full grain (14% m.c.)	No. of panicles per hill	No. of spikelets per panicle	Percentage of ripened grains	Weight of 1,000 full grains
		t/ha			%	g
P_1	C_1	2.62	10.1	107.2	62.0	26.2
	C_2	3.03	10.2	111.2	70.5	25.9
	C_3	3.07	10.4	110.1	69.9	26.2
P_2	C_1	2.87	10.1	106.1	74.3	26.2
	C_2	2.82	10.4	105.4	67.2	25.9
	C_3	2.83	10.2	104.4	68.4	25.8
P_3	C_1	2.84	10.2	106.7	71.3	26.1
	C_2	2.79	10.0	104.3	71.5	26.3
	C_3	2.95	10.6	104.6	72.0	26.2

Table 1-4. Population of weeds in paddy field

(per $10m^2$)

Treatment		Monocotyledon		Dicotyledon		Total	
		Number	Fresh weight	Number	Freish weight	Number	Fresh weight
			g	g	g		g
P_1	C_1	160	561	237	310	397	871
	C_2	164	457	252	309	416	873
	C_3	144	458	227	292	371	829
P_2	C_1	11	130	12	29	23	159
	C_2	18	132	14	22	32	154
	C_3	8	92	7	22	15	114
P_3	C_1	10	127	2	9	12	136
	C_2	8	75	9	24	17	99
	C_3	15	180	4	22	19	202
F value on each treatment by analysis of variance							
P		40.38***	7.45**	45.03***	26.42***	45.52***	12.09***
	P_1: $P_{2,3}$	80.75***	14.89**	90.02***	52.82***	91.02***	21.97***
	P_2: P_3	—	—	—	—	—	—
C		—	—	—	—	—	—
P × C		—	—	—	—	—	—

Remarks 1) Weed population was determined on Aug. 26.
2) Signs of ***, ** and — indicate significance with 0.1% level, 1% level and no significance, respectively.

Table 1-5. Periodical changes of moisture content, hardness and bulk density of soil

		Nov. 27			Dec. 3[1]			Dec. 11[2]			Dec. 16[3]		
		Mc %	Hd mm	Bd	Mc %	Hd mm	Bd	Mc %	Hd mm	Bd	Mc %	Hd mm	Bd
P_1	C_1	30.8	3.3	1.19	30.3	17.8	1.19	21.2	28.4	1.12	20.0	30.4	1.27
	C_2	32.0	3.4	1.17	26.3	14.3	1.17	20.1	29.0	1.26	18.6	30.4	1.23
	C_3	30.9	3.0	1.25	29.2	16.6	1.19	19.0	27.9	1.21	16.6	29.7	1.38
P_2	C_1	31.1	3.8	1.24	30.5	20.8	1.31	22.0	27.0	1.28	20.0	31.3	1.38
	C_2	35.2	3.4	1.14	28.3	20.5	1.28	22.1	29.0	1.24	18.0	30.3	1.40
	C_3	32.2	4.0	1.11	31.3	22.7	1.14	22.2	28.2	1.24	20.2	29.5	1.30
P_3	C_1	34.5	3.5	1.20	29.2	20.0	1.29	24.6	27.4	1.34	22.4	30.3	1.30
	C_2	33.4	3.2	1.18	26.5	23.7	1.35	23.0	28.6	1.38	21.5	32.1	1.39
	C_3	32.0	3.5	1.16	28.9	23.6	1.31	24.3	27.8	1.35	23.8	29.8	1.27

Remarks: 1), 2) and 3 respectively indicate the date on which first tilling for M_3, M_2 and M_1 plots were made.
Mc: moisture content
Hd: hardness (measured by soil hardness meter)
Bd: bulk density
The Atterberg limit of the soil is as follows:
Liquid limit (LL): 39.70%
Plastic limit (PL): 17.70%
Plastisity index (Ip): 22.00

Table 1-6. Growth of succeeding upland crops

Treatment	Plant height cm	Dry weight g/m^2
M_1	121.0	402.3
M_2	122.6	402.1
M_3	65.6	108.0
P_1	103.8	313.0
P_2	103.1	310.0
P_3	102.2	289.4
C_1	100.6	297.4
C_2	104.2	311.1
C_3	104.3	303.9

Note: Plant growth was checked on 9 weeks after seeding.
Figures show the average of 9 crops.

Table 1-7. Analysis of variance on the growth of succeding upland crops

Factor	d.f.	s.s.	m.s.	F
(Plant height)				
Total	26	50,581		
M	2	18,977	9,489	6.02**
($M_{1,2}$: M_3	1	18,966		12.03**
\ M_1: M_2	1	11		—
P	2	11	6	—
C	2	83	44	—
error	20	31,510	1,576	
Dry weight				
Total	26	622,345		
M	2	519,400	259,700	52.00***
($M_{1,2}$: M_3	1	519,400		>100***
\ M_1: M_2	1	0		—
P	2	2,959	1,480	—
C	2	841	421	—
error	20	99,145	4,957	

Note: L_{27} (3^{13}) table was employed for the analysis of variance. A variane of all interactions between and among the factors were included in the item of error.

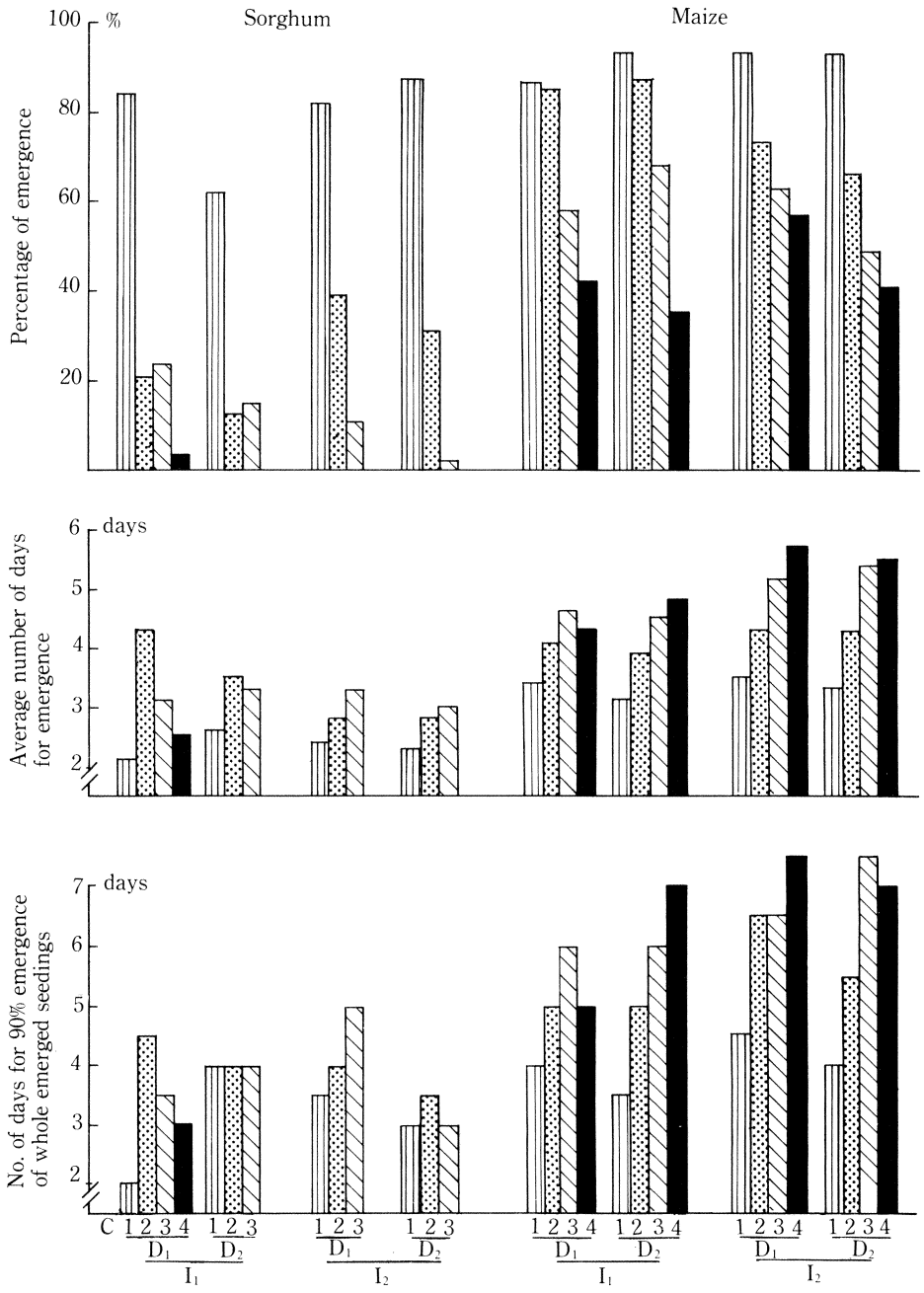

Fig. 1-1. Emergence of seedlings with special reference to clod size of soil

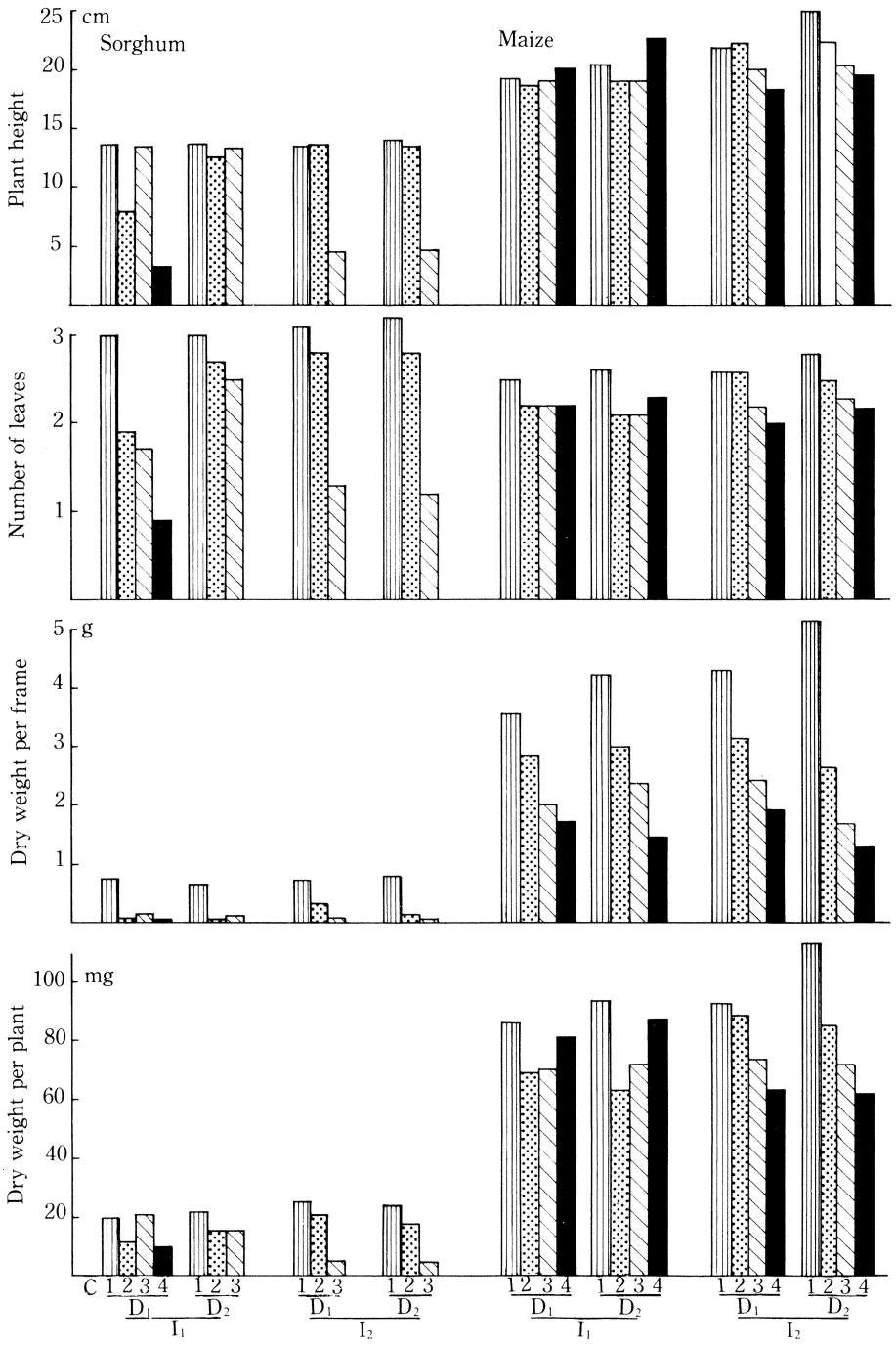

Fig. 1-2. Growth of seedlings with special reference to clod size of soil

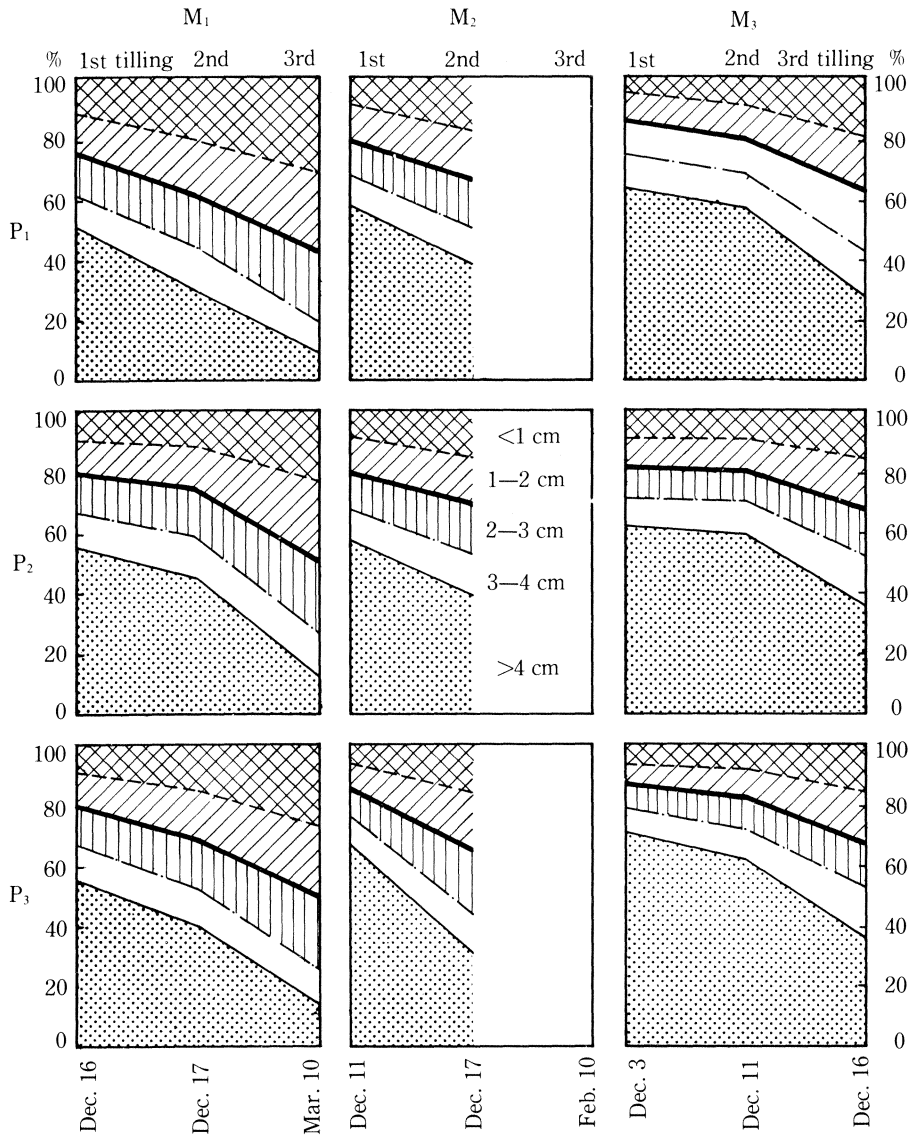

Fig. 1-3. Clod size distribution

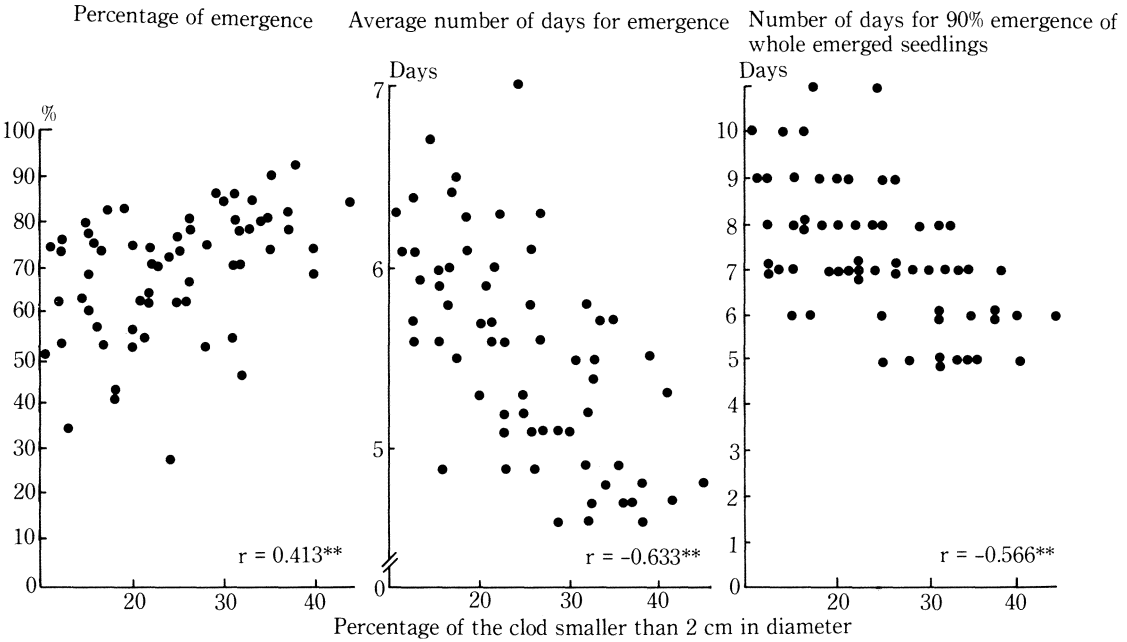

Fig. 1-4. Relation between percentage of small clod of soil in the seed bed and seedling emergence of maize