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EFFECT OF THE DIKE HEIGHT ON WATER, SOIL AND NUTRIENT CONSERVATION, AND RICE YIELD

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1. INTRODUCTION

Soil and Water are the two basic natural resources whose conservation and management are gaining importance over period of time for sustainable agriculture. The eastern region of India is bestowed with plenty of rainfall. Mean annual rainfall of this region varies from 1007 mm (eastern Uttar Pradesh) to 3126 mm (sub Himalayan West Bengal). Bulk of this rain (about 80%) occurs during monsoon season. Because of excessive rainfall, paddy is the predominant crop of this region. During the year 1994-95 the total cultivated area under rice in the whole country is recorded as 42.24 M ha (million hectare) and the productivity as 1921 kg/ha. Similarly the area under rice in the eastern region is recorded as about 21 M ha with productivity of 1586 kg/ha. Thus, eastern region has about 50% of the country's rice area, and its productivity at the moment is 335 kg/ha less than country's average productivity (Agricultural Statistics at a glance, 1996). The states like Assam, Bihar, Orissa and eastern Madhya Pradesh have registered a very low productivity figures. In order to bring improvement in rice yield of this region one needs to know the problems which are responsible for such a low yield.

In rainfed areas with lack of sources for irrigation water, the general tendency of the farmers is to store maximum rain water in the cropped fields to avoid moisture deficiency during dry spells. This storage is achieved by strengthening the bund height. Since rainfall is a stochastic phenomenon, the hydrograph of ponding in the rice fields is also stochastic. Excessive rainfall sometimes leads to submergence of crop whose degree and duration are also stochastic. Due to this submergence, a substantial damage to crops and yields take place. On the other hand, long dry spells at critical stages of crop growth cause moisture deficiency. Hence, there is a need to determine the optimum height of the bund so that there is maximum utilization of rain water without any adverse effect on crop growth and yield.

2. EXPERIMENTAL LAYOUT

Experiment was conducted in nicely levelled field plots of 36 m X 10 m size surrounded by 45 cm height of bunds. Polythene sheets of 200 micron gauge were embedded within the bund vertically to a depth of 60 cm below the ground level to minimize seepage loss from one field to another. Seven different weir heights were selected as treatments for allowing the excess water to spill over them with three replications each. The heights of the weir so chosen were 6 cm, 10 cm, 14 cm, 18 cm, 22 cm, 26 cm and 30 cm. Multislot divisors were installed at the down stream end of each plot. The central slot was connected with the rainfall excess collection tank for monitoring of daily rainfall excess amount. Isometric view of the multislot divisor showing its dimension details is drawn in Fig. 1.

Three varieties of rice namely IR-36 (semi-dwarf medium duration), Mashuri (tall and medium long duration) and CR-1009 (tall and long duration) were grown in each plot (each variety occupying 1/3 area of individual plot) to study the effect of different levels of ponding on their growth and yield in natural field situations. Plant spacing of 20 X 15 cm was maintained and a fertilizer dose of 60:30:30 (N:P:K) in kg/ha was applied during the experimental years in three split doses. These three split doses consist of a basal dose of 30:30:30 (N:P:K), two top dressing doses of nitrogen @ of 15 kg/ha during tillering and panicle initiation stages.

Various components of water balance such as rainfall, rainfall excess from each plot, evaporation, evapotranspiration and deep percolation losses were monitored daily during the crop growth period. Water levels in each plot were monitored daily to compare the hydrograph of ponding in rice fields at various weir heights. Biometric observations such as leaf area index, number of tillers per square meter area and plant height at periodic intervals were recorded. Yield and yield components were also recorded. Loss of sediment and nutrients in runoff water coming out of the experimental plots were monitored.

3. RESULTS AND DISCUSSION

The experiment was initiated in the year 1992 and during this year only Mashuri variety of rice was grown. In the subsequent years i.e., during 1993, 1994 and 1995 three varieties of rice as stated above were grown and the transplanting was done during 3rd week of July, 4th week of July and Ist week of August respectively. Treatments were imposed after about 7 days of transplanting and observation on various hydrologic and biometric parameters were recorded since then till the harvesting of crop.

3.1 Components of Water Balance

Measurements of evaporation, evapotranspiration, deep percolation and seepage loss, rainfall excess, fluctuation of water level in the rice field and rainfall were recorded daily for all the treatments. Results on different components of water balance based on three years of field study are given in Table 1.

3.1.1 Evapotranspiration

Evapotranspiration rates were recorded for all the treatments with the help of Lysimeters installed in each plots and no significant difference in ET values was observed amongst various treatments. However it is clear that CR-1009 registers highest ET followed by Mashuri and IR-36. All the varieties have recorded lower ET values at initial stage of crop growth, higher ET during full growth stage and subsequent decline in ET values at crops maturity. A typical curve of evapotranspiration rate over the crop growth period (for the year 1994) is shown in Fig. 2.

3.1.2 Evaporation

A decrease in the rate of evaporation has been observed with the advancement of crop growth, which is possibly due to the increase in shading effect of crop canopy. Evaporation rate ranged from 2.20 to 3.80 mm/day and the average rate of evaporation from the experimental field is observed as 3.00 mm/day. A typical evaporation curve for the crop growth period of 1994 is shown in Fig. 3.

Figure 4 shows the plotting of the ratio of evaporation to evapotranspiration against the age of the rice plant (in weeks). Observation was taken when the crop was 7 weeks old i.e., two weeks after the transplanting. At the initial stage the ratio is found to be between 0.9 and 0.95. With the advancement of crop growth the ratio is found to be decreasing. However a couple of weeks before the harvesting the ratio is found to have increased little bit which is due to the drooping down of rice plant leaves. On correlation, a power function is found to be best fit relation between E/ET ratio and age of rice plant in weeks. The equations obtained are as follows;

$$(E/ET)_{IR\text{-}36} = 3.892\,(A_w)^{-0.086}, \qquad R^2 = 0.782 \qquad ...(1)$$

$$(E/ET)_{Mashuri} = 2.061\,(A_w)^{-0.54}, \qquad R^2 = 0.547 \qquad ...(2)$$

$$(E/ET)_{CR\text{-}1009} = 4.455\,(A_w)^{-0.886}, \qquad R^2 = 0.763 \qquad ...(3)$$

$$(E/ET)_{Pooled,\ Var.} = 2.863\,(A_w)^{-0.684}, \qquad R^2 = 0.711 \qquad ...(4)$$

where, E is the average evaporation rate from the paddy field, mm/day; ET is the average evapotranspiration rate from the paddy field, mm/day; and A_w is the age of rice plant in number of weeks.

3.1.3 Deep percolation and seepage

Deep percolation and seepage losses were found to be increasing with the increase in weir height. This confirms to finding of earlier investigators that increased depth of ponded water increase percolation due to the larger gradient in hydraulic head imposed (Sanchez, 1973; Wickham and Singh, 1978). The values of deep percolation and seepage ranged from 2.60 to 5.60 mm/day, 1.70 to 4.40 mm/day and 1.70 to 6.00 mm/day for the year 1993, 1994 and 1995, respectively. The average value are found to be 3.90, 3.40, 3.00 and 3.80 mm/day for the year 1992, 1993, 1994 and 1995, respectively. Hence taking mean of all the years, the average rate of deep percolation and seepage is obtained as 3.50 mm/day.

The data on deep percolation and seepage loss for the year 1995, when plotted against the weir height yields a power function relationship as given below.

$$DP = 0.46\,(H)^{0.705}, \qquad R^2 = 0.812 \qquad ...(5)$$

where, DP is the rate of deep percolation and seepage, mm/day; and H is the weir height, cm.

Average depth of water ponded in the rice field during the crop growth period is found to have increased with the increase in weir height. For the year 1995, a linear relationship has been observed between the average depth of water ponded and the depth of water lost due to deep percolation and seepage which is as follows;

$$DP = -\,1.64 + 0.79\,D, \qquad R^2 = 0.865 \qquad ...(6)$$

where, D is average depth of water ponded or stored in the rice field in a crop growing season in cm and DP is average depth of water lost due to deep percolation and seepage in mm/day. Equation (6) implies that deep percolation is zero up to the average depth of 2.08 cm. Thus the hydraulic gradient corresponding to 2.08 cm depth of ponding is the threshold value after which the deep percolation and seepage takes place. It is probably due to the deposition of a fine soil layer at the land surface on account of puddling. Puddling induces non Darcian flow at lower hydraulic gradients. Evidently in puddled fine textured soil a critical hydraulic gradient exists beyond which the water flux is Darcian and before which it remains non Darcian (Sinha, Singh and Sharma, 1981).

3.1.4 Evapotranspiration + deep percolation and seepage loss

Total depth of water lost from paddy field due to ET + deep percolation and seepage are found to be varying from 6.20 to 9.40 mm/day and 6.80 to 11.2 mm/day for the year 1994 and 1995, respectively. The average value is calculated as 8.70 mm/day.

3.1.5 Rainfall excess

There is hardly any information available about the rainfall excess amount which comes out of rice fields having various bund heights. A study in the BRRI farm, Bangladesh with different levee heights indicates that the effectiveness of rainfall was higher (71% - 100%) with a levee height of 15 cm when compared to 7.5 cm (55% - 100%) and no levee at (37% - 92%) treatments (Islam and Mondal, 1992). Therefore, one of the important aspect of this experiment was to quantify the rainfall excess coming out of various weir height plots. A perusal of Table 2 shows that in the year 1993, there was only run off water up to 14 cm weir height plots. Other two years had runoff water from all the treatments. During the crop growth period of 1993, 1994 and 1995 a rainfall of 588.30, 1020 and 628.90 mm, respectively were recorded. Considering weighted average of rainfall excess for three years, it is found that as high as 57 % of rainfall was stored in the 6 cm weir height plots and about 99.5 % of the rainfall was stored in 30 cm weir height plots. These rainfall excess values when plotted against the weir heights yield an exponential relationship which is as follows;

$$RE = 121.75\ e^{-0.181\,H}, \qquad R^2 = 0.967 \qquad \ldots (7)$$

where, RE is rainfall excess as percentage of rainfall and H is weir height, cm.

A perusal of the Fig. 5 reveals that the slope of the curve after 22 cm weir height is seen to have become relatively flat than the slope before. Hence it is clear that bund height beyond 22 cm height will store very little amount of additional rain water. Similar exponential relationship has also been found for individual years data. They are as follows;

$$RE_{1993} = 384.91\ e^{-0.410\,H}, \qquad R^2 = 0.792 \qquad \ldots(8)$$

$$RE_{1994} = 153.24\ e^{-0.212\,H}, \qquad R^2 = 0.882 \qquad \ldots(9)$$

$$RE_{1995} = 93.41\ e^{-0.130\,H}, \qquad R^2 = 0.936 \qquad \ldots(10)$$

3.2 Hydrograph of Ponding

Daily measurement of the depth of standing water in the plots were taken to know the hydrograph of ponding during the crop growth period. Figure 6 shows the hydrograph of ponding in various treatments for the year 1995. Table 3 shows the average depth of water stored for crop growth period for different years of experiment for IR-36, which is a medium duration crop. The average depth of water stored (taking average of three years) in 6 cm, 10 cm, 14 cm, 18 cm, 22 cm, 26 cm and 30 cm weir height plots are obtained as 4.47 cm, 7.02 cm, 7.10 cm, 8.22 cm, 8.68 cm, 9.02 cm and 9.91 cm, respectively. Similarly for Mashuri and CR-1009 (which are medium long duration and long duration crop, respectively) the average depth of water stored in various weir height plots are shown in Table 4 and 5, respectively. On correlating the seasonal average depth of water stored with the weir height, logarithmic form of equation found to be best fitted. The following equations are obtained.

$$Y_{IR\text{-}36} = -0.719 + 3.069\,Ln(H), \qquad R^2 = 0.961 \qquad ...(11)$$

$$Y_{Mashuri} = -1.024 + 2.871\,Ln(H), \qquad R^2 = 0.960 \qquad ...(12)$$

$$Y_{CR\text{-}1009} = -0.489 + 2.58\,Ln(H), \qquad R^2 = 0.968 \qquad ...(13)$$

where, Y is seasonal average depth of water stored or ponded in cm, and H is weir height in cm.

3.3 Loss of Sediments in Runoff Water

Loss of sediments in runoff water was monitored by collecting the water samples of runoff water on various days. The total loss of sediments from rice field in a cropping season has been shown in Table 6. As high as 347.78 Kg/ha of sediment is lost from a paddy field with 6 cm bund height and 3.31 kg/ha is lost from a paddy field with 30 cm bund height. Therefore, the amount of sediment which is lost in one year (cropping season) from 6 cm weir height plots will take almost 106 years (cropping season) for 30 cm weir height plots. Hence, this analysis emphasizes that determination of optimum bund height should not be decided only from rainwater conservation angle but also from the angle of soil conservation. Sediment loss when plotted against weir height (Fig. 7), yields an exponential relationship which is as follows;

$$S = 810.78\,e^{-0.166\,H}, \qquad R^2 = 0.945 \qquad ...(14)$$

where, S is loss of sediments, kg/ha and H is weir height, cm.

3.4 Loss of Nutrients in Runoff Water

Loss of nutrients like total Kjeldahl Nitrogen (TKN) and available potassium were monitored in the runoff water (Table 6). It is to mention here that chemical fertilizers @ 60:30:30 (N:P:K) kg/ha were applied to the crop at three splitting doses. As high as 4.23 kg of TKN and 2.20 kg of available potassium are observed to be lost through runoff water from 6 cm weir height plots in one cropping season. A very negligible amount of TKN and potassium loss are recorded from 30 cm weir height plots. Runoff losses to the extent of 4 -16 kg N/ha from applied urea have been reported by Singh, *et al.*, 1977 and Takamura *et al.*, 1977.

On analyzing the nutrient loss data, it is found that the TKN which is lost in one year from 6 cm weir height plot will take about 33 years to get lost from 22 cm weir height plots. Similarly for potassium, the amount which is lost from 6 cm weir height plot will take about 50 years to get lost from 30 cm weir height plots. A decreasing trend of these losses is observed with the increase in weir height (Fig. 8). Like sediment loss, losses of nutrients when correlated with weir heights also results in following relationships.

$$TKN = 25.25\ e^{-0.23\ H}, \qquad R^2 = 0.904 \qquad ...(15)$$

$$P = 4.81\ e^{-0.168\ H}, \qquad R^2 = 0.904 \qquad ...(16)$$

where, TKN is total Kjeldahl nitrogen loss in kg/ha, P is available potassium loss in kg/ha, and H is weir height in cm.

3.5 Application of Irrigation Water

Irrigation was applied a number of times during dry spells. Application of irrigation water was made just a day after the standing water completely vanished from the field and during each irrigation a depth of 6 cm water was applied. Table 7 shows the number of irrigations which were applied for various treatments during different years. On an average four irrigations are applied for 6 cm weir height plots. Three irrigations are applied for 10 and 14 cm weir height plots. Eighteen cm and above weir height plots required only two irrigations per crop growth period. Therefore, it is clear that 6 cm weir height plot requires twice the number of irrigations required for 18 cm and above weir height plots.

3.6 Growth and Yield of Different Rice Varieties as Affected by Various Weir Heights/ Ponding Depths

Biometric observations such as leaf area index (LAI), number of tillers per square meter area, and plant height were recorded at periodic intervals during the crop growth period. Grain and straw yield of the experimental plots were also recorded. An attempt has been made to observe the effect of weir height/ponding depth on these parameters of different rice cultivars.

3.6.1 Cultivar Mashuri

Mashuri is a tall and medium long duration crop. The seasonal average depth of water stored due to various weir heights (6 cm to 30 cm) varies from 4.15 to 9.20 cm (Table 4). Three years result showed that these weir heights or corresponding seasonal stored water depths could not bring any significant impact on yield of Mashuri. A declining trend in rice yield has been recorded due to greater ponding from 4.15 to 9.20 cm. Mashuri recorded higher yield at 6 cm weir height (2065 kg/ha) which has an average standing water depth of 4.15 cm during crop growth period. Chandramohan (1970) reported that 5 cm submergence was better for higher rice yield.

The said water levels (i.e., 4.15 to 9.20 cm) also could not bring any significant impact on leaf area index and effective tillers of Mashuri (Tables 8 and 14). The plant height (Table 11) increased due to more ponding and varied from 103 cm to 110 cm which confirms to the findings of Chatterjee and Maity (1983) that the rice plant height are directly proportional to ponding depth. Under different water levels the LAI varied from 2.32 to 3.33 and effective tillers from 181 to 239 per square meter (Tables 8 and 11, respectively). Hence it is concluded that the rice cultivar Mashuri can tolerate an average submergence of 4.15 to 9.20 cm without any significant damage to the crop growth and yield. Thus there is a scope of harvesting almost entire rainfall during the rainy season in the rice field where Mashuri is cultivated without any significant reduction in crop yield.

3.6.2 Cultivar IR-36

IR-36 is a semi-dwarf medium duration crop. The seasonal average depth of water stored found to be ranging from 4.47 cm (for 6 cm weir height plot) to 9.91 cm (for 30 cm weir height plot). This variety recorded rice yield of 2115 to 2428 kg/ha due to different ponding situations according to weir constructed (Table 18). The rice yields are not significantly different due to different levels of water stored at different weir heights. It recorded highest grain yield of 2428 kg/ha at 14 cm weir height where the seasonal average water stored depth was 7.10 cm. Bhatia and Dastane (1971) reported 0-4 cm submergence to be optimum for dwarf high yielding varieties.

Different weir heights and their corresponding stored water depths could not affect significantly the leaf area index and effective tillers of rice crop (Tables 9 and 15). The rice plant height varied from 72 to 76 cm as the ponding depth increased (Table 12). Leaf area index at 60 DAT varied from 1.85 to 2.48 and effective tillers from 357.31 to 421.10 per square meter area (Table 9 and 15 respectively). Hence, this variety (IR-36) is observed to have tolerance to a seasonal average stored water depth of 4.77 to 9.91 cm during its growth phase.

3.6.3 Cultivar CR-1009

This rice cultivar was exposed to a seasonal average stored water depth of 3.99 to 8.58 cm (Table 4) for three years consecutively. CR-1009 recorded rice yield of 2839 to 3136 kg/ha at various ponding situations according to weir constructed (Table 19). Rice grain yield were not significantly different due to different stored water levels under various weir heights. It recorded highest grain yield of 3136 kg/ha at 22 cm weir height plots where seasonal average stored water depth was 7.39 cm.

Different weir heights and its corresponding stored water depths could not affect significantly the leaf area index and effective tillers of rice cultivar CR-1009 (Tables 10 and 16). The rice plant height varied from 91.45 cm to 96.00 cm as the ponding increased (Table 13). Under different water levels the LAI at 60 DAT varied from 2.71 to 3.33 and effective tillers from 239 to 273 per square meter area respectively (Tables 10 and 16). Variety CR-1009 has therefore got resistance to an average stored water depth of 3.99 to 8.58 cm during its growth period.

3.6.4 Growth curve of different cultivars under various weir heights

Plant heights of different rice cultivars under various treatments were monitored at weekly interval. Figure 9 shows the growth curve of IR-36 for various treatments during the year 1995. Though at the beginning the height remained same for all the treatments but at maturity a difference in heights can be seen. Plants found to be shorter at lower weir heights and vice versa at higher weir heights. Similarly for Mashuri and CR-1009, 6 cm weir height plots have produced shorter plants. Not much difference in plant height at higher weir heights is seen. The average plant height of all treatments when correlated with the number of weeks after transplanting, a power function relationship for IR-36 and Mashuri and an exponential relationship for CR-1009 were obtained. The best fit equations of the average growth curve are as follows;

$$h_{IR-36} = 33.415\,(w)^{0.351}, \qquad R^2 = 0.966 \qquad ...(17)$$

$$h_{Mashuri} = 35.446\,(w)^{0.475}, \qquad R^2 = 0.97 \qquad ...(18)$$

$$h_{CR\text{-}1009} = 37.637\, e^{0.073\,(w)}, \qquad R^2 = 0.988 \qquad ...(19)$$

where, w is the weeks after transplanting, and h is the average plant height in cm.

3.6.5 Grain yield analysis

Grain Yield of three varieties of rice are shown in Tables 17, 18 and 19. The highest yield of IR-36 was obtained in 14 cm were height plots. The second highest in 22 cm weir height plots. The difference amongst treatment means is found to be statistically non significant. Similarly for mashuri the highest yield is obtained in 6 cm weir height plots and the second highest in 22 cm weir height plots. The highest yield of CR-1009 is obtained from 22 cm plots and second highest in 6 cm weir height plots. Keeping all the factors of production same, CR-1009 is found to have better productivity in comparison to Mashuri and IR-36.

Grain yield when plotted against weir height (Fig. 10) a slight decreasing trend in the yield with the increase in weir height is seen for IR-36 and Mashuri. CR-1009 give a slight increasing trend with increase in weir height.

Plot of dimensionless grain yield with various weir heights (Fig. 11) shows that highest reduction in yield has been noticed for IR-36 (about 15%). Hence IR-36 amongst these three varieties can be considered as more sensitive to water ponding followed by Mashuri and CR-1009.

3.7 Bund Height at Farmers Field

In order to have an idea of the existing bund heights at farmers field, measurements of bund height in few rice plots of the farmers located close to experimental site was undertaken. Considerable variation in height of the bunds (when four sides of the plots are considered) was observed in a particular plot. Minimum bund height of 10 cm and maximum bund height of 55 cm were recorded. The average bund height of all surveyed fields (8 fields) was found to be 24 cm.

4. CONCLUSIONS

The results of the three years of experimental field plots study on rice crop during kharif season with seven different weir heights of 6 cm, 10 cm, 14 cm, 18 cm, 22 cm, 26 cm and 30 cm as treatments at WTCER research farm, Mendhasal reveal the following conclusions.

(a) Rice plots with bund height of 6 cm and 30 cm can store 57 % and 99 % of the rain water. An exponential relationship has been observed between the rainfall excess values as percentage of rainfall and weir heights.

(b) On an average four irrigations with an application depth of 6 cm per irrigation were found to be required for 6 cm weir height plots. Three irrigations were required for 10 and 14 cm weir height plots. Eighteen cm and above weir height plots required only two irrigations per crop growth period.

(c) The seasonal average depth of water stored was observed to be ranging from 4.47 cm to 9.91 cm (for IR-36), 4.15 cm to 9.20 cm (for Mashuri), and 3.99 cm to 8.58 cm (for CR-1009) for 6 cm to 30 cm weir height plots, respectively.

(d) Average depth of water lost due to evaporation is observed as 3.00 mm/day. Similarly average depth of water lost due to deep percolation and seepage is found to be 3.5 mm/day. Average depth of daily water loss due to evapotranspiration and deep percolation and seepage was observed as 8.7 mm/day (for all treatments).

(e) Loss of sediments, nutrients such as TKN and available potassium in runoff water are found to be exponentially related with weir heights. Six cm weir height plots have recorded highest loss of sediment (347.78 kg/ha) and nutrients (4.227 kg/ha of TKN and 2.20 kg/ha of Potassium). At the weir height of 22 cm these losses have been minimized to a considerable extent.

(f) Biometric observations such as leaf area index, plant height, number of tillers per quare meter area observed to be statistically non significant amongst various weir height plots.

(g) Grain yield of three varieties of rice for various treatments also found to be statistically non significant. Plot of dimensionless grain yield versus weir height shows that 6 and 22 cm weir height plots have done well for all three varieties. Amongst the three cultivars, IR-36 have registered highest reduction (about 15 %) in grain yield.

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Table 1. Components of water balance in the experimental rice fields.

Year	Evapotranspiration loss mm/day		Deep percolation loss mm/day
1992	Mashuri	4.40 - 6.80	3.90
1993	IR-36 Mashuri CR-1009	3.20 - 6.20 4.00 - 8.10 2.90 - 7.50	3.40
1994	IR-36 Mashuri CR-1009	3.80 - 7.10 3.70 - 7.40 4.00 - 8.30	3.00
1995	IR-36 Mashuri CR-1009	2.90 - 8.20 2.00 - 7.50 4.50 - 7.30	3.80

Average value of evaporation ranges from 2.20 to 3.80 mm/day.

Average value of deep percolation loss is observed as 3.50 mm/day.

Average value of total depth of water lost from the field due to evapotranspiration,deep percolation and seepage is observed as 8.70 mm/day.

Table 2. Rainfall excess as percentage of rainfall.

Weir height, cm	Rainfall excess as percentage of rainfall			
	1993	1994	1995	Weighted average
6	29.92	48.18	47.65	43.25
10	23.51	25.88	35.36	27.93
14	6.20	4.67	8.59	6.18
18	0.00	5.08	9.30	4.93
22	0.00	0.43	5.07	1.62
26	0.00	1.40	2.73	1.41
30	0.00	0.27	2.39	0.57

Note: Total rainfall during the observation period (transplanting to harvesting) for the year 1993, 1994 and 1995 were observed as 588.30, 1020 and 628.90 mm respectively.

Table 3. Treatmentwise average depth of water stored in cm (IR-36).

Weir heights, cm	Experimental Years			Average of three years
	1993	1994	1995	
6	5.03	3.46	4.92	4.47
10	6.73	6.99	7.35	7.02
14	7.10	7.41	6.79	7.10
18	6.98	8.05	9.63	8.22
22	8.76	8.89	8.40	8.68
26	9.02	8.39	9.66	9.02
30	10.40	8.73	10.59	9.91

Table 4. Treatmentwise average depth of water stored in cm (Mashuri).

Weir heights cm	Experimental Years			Average of three years
	1993	1994	1995	
6	4.93	3.16	4.35	4.15
10	5.88	6.33	5.43	5.88
14	6.09	6.50	5.69	6.09
18	7.20	6.77	8.14	7.37
22	8.37	7.63	7.46	7.82
26	8.52	7.53	7.80	7.95
30	10.27	7.69	9.65	9.20

Table 5. Treatmentwise average depth of water stored in cm (CR-1009).

Weir heights, cm	Experimental Years			Average of three years
	1993	1994	1995	
6	4.93	3.16	4.47	3.99
10	5.88	6.33	5.58	5.88
14	6.09	6.50	6.09	6.09
18	7.20	6.77	6.97	6.97
22	8.37	7.63	7.39	7.39
26	8.52	7.53	7.66	7.66
30	10.27	7.69	8.44	8.58

Table 6. Loss of sediment, total Kjeldahl nitrogen and potassium in runoff water from rice fields with various weir heights.

Weir height, cm	Total sediment loss, kg/ha	Total Kjeldahl nitrogen loss, kg/ha	Total potassium loss, kg/ha
6	347.778	4.227	2.199
10	120.310	3.192	1.395
14	65.694	0.776	0.350
18	39.361	0.721	0.132
22	28.528	0.130	0.064
26	17.639	0.172	0.094
30	3.305	0.00	0.044

Table 7 : Number of irrigations applied during different years in rice fields with various weir heights.

Weir heights, cm	Number of irrigations applied during different years				Average (rounded up)
	1992	1993	1994	1995	
6	3.00	5.00	5.00	1.00	4.00
10	2.00	4.00	3.00	1.00	3.00
14	2.00	4.00	3.00	1.00	3.00
18	2.00	3.00	3.00	0.00	2.00
22	1.00	3.00	3.00	0.00	2.00
26	1.00	4.00	3.00	0.00	2.00
30	1.00	4.00	4.00	1.00	2.00

Table 8 : LAI of Mashuri at 60 DAT during different years for various weir height plots.

Weir height, cm	LAI at 60 DAT during different years				Average
	1992	1993	1994	1995	
6	1.67	2.65	3.82	4.16	3.07
10	1.27	3.23	2.24	2.55	2.32
14	1.74	3.54	3.53	4.52	3.33
18	1.54	3.56	2.67	3.46	2.81
22	2.40	2.36	1.91	4.26	2.73
26	1.49	3.65	2.74	4.25	3.03
30	1.55	3.53	1.64	3.06	2.44

Table 9 : LAI of IR-36 at 60 DAT during different years for various weir height plots.

Weir height, cm	LAI at 60 DAT during different years			Average
	1993	1994	1995	
6	2.30	3.00	2.13	2.48
10	2.14	1.78	2.09	2.00
14	1.92	1.84	1.79	1.85
18	2.36	1.95	2.32	2.21
22	2.33	1.41	2.44	2.06
26	2.95	1.67	2.53	2.38
30	2.39	1.61	3.05	2.35

Table 10 : LAI of CR-1009 at 60 DAT during different years for various weir height plots.

Weir height, cm	LAI at 60 DAT during different years			Average
	1993	1994	1995	
6	2.65	2.34	3.15	2.71
10	3.23	2.18	3.38	2.93
14	3.54	2.77	3.67	3.33
18	3.56	1.71	4.66	3.31
22	2.36	1.55	4.66	2.86
26	3.65	2.06	3.52	3.08
30	3.53	1.40	3.93	2.95

Table 11 : Plant height of Mashuri at maturity in cm from various weir heights plots.

Weir height, cm	Plant height in cm during different years				Average plant height
	1992	1993	1994	1995	
6	83.32	117.40	95.73	118.36	103.71
10	83.01	117.25	97.40	112.73	102.59
14	87.39	122.01	101.86	120.88	108.06
18	93.68	119.61	103.06	111.90	107.06
22	96.78	122.93	105.96	114.82	110.12
26	96.83	116.43	105.69	120.76	109.93
30	92.72	118.34	98.47	116.51	106.51

Table 12 : Plant height of IR-36 at maturity in cm from various weir heights plots.

Weir height, cm	Plant height during different years			Average
	1993	1994	1995	
6	68.21	77.73	69.94	71.96
10	69.38	76.90	79.63	75.31
14	66.69	65.49	71.72	67.97
18	71.73	78.98	76.22	75.64
22	68.30	77.36	73.33	72.99
26	69.68	77.45	73.36	73.49
30	70.35	77.06	77.34	74.91

Table 13 : Plant height of CR-1009 at maturity in cm from various weir heights plots.

Weir height, cm	Plant height during different years			Average plant height, cm
	1993	1994	1995	
6	94.68	87.30	92.37	91.45
10	97.87	83.66	97.12	92.88
14	94.19	85.43	95.92	91.85
18	92.31	86.35	101.22	93.29
22	98.09	89.92	99.53	95.85
26	98.24	87.24	100.08	95.43
30	96.33	84.22	98.78	93.11

Table 14 : Number of effective tillers/m^2 area of Mashuri from various weir height plots.

Weir height, cm	No. of effective tillers/square meter area				Average
	1992	1993	1994	1995	
6	254.67	244.03	201.41	204.31	226.10
10	261.67	251.81	198.98	224.31	234.19
14	315.00	255.69	183.32	190.98	236.25
18	216.67	265.42	159.42	260.98	225.62
22	274.67	210.00	192.55	178.98	214.05
26	227.00	280.97	231.41	215.65	238.76
30	188.67	220.69	109.19	208.98	181.88

Table 15 : Number of effective tillers/m^2 area of IR-36 from various weir height plots.

Weir height, cm	No. of effective tillers/sq. m area			Average plant
	1993	1994	1995	
6	348.06	427.62	408.85	395.03
10	412.22	380.29	446.62	413.05
14	425.83	357.30	404.40	395.84
18	366.53	347.07	357.74	357.31
22	418.06	356.30	366.63	380.51
26	472.50	334.17	456.62	421.10
30	393.75	356.30	364.96	371.67

Table 16 : Number of effective tillers/m^2 area of CR-1009 from various weir height plots.

Weir height, cm	No. of effective tillers/sq. m area			Average
	1993	1994	1995	
6	300.42	222.21	193.31	238.65
10	348.05	231.41	232.31	270.74
14	318.88	261.97	240.97	273.94
18	303.33	247.21	198.98	249.84
22	282.92	261.07	226.64	257.10
26	311.12	210.21	208.98	243.44
30	297.50	268.54	253.31	273.12

Table 17 : Grain yield of Mashuri in Kg/ha from rice plots with various weir heights.

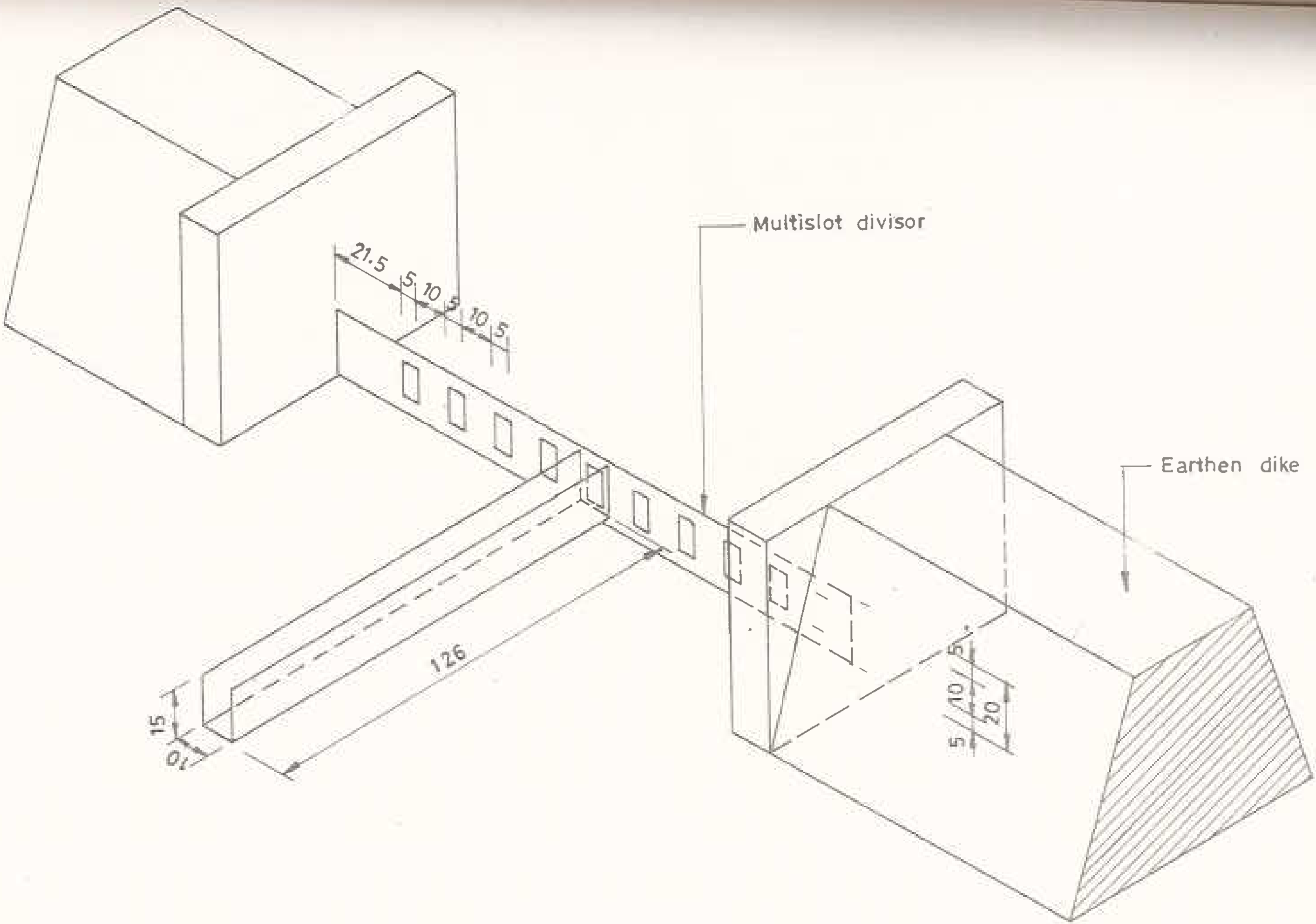
Weir height, cm	Grain yield in Kg/ha during different Years				Average
	1992	1993	1994	1995	
6	1831.06	3287.80	1690.92	1451.07	2065.21
10	1805.69	2708.57	1473.87	1397.07	1846.30
14	1950.88	2740.55	1559.56	1185.37	1859.09
18	1760.09	2907.41	1582.44	1274.51	1881.11
22	1819.17	2582.35	1665.26	1814.48	1970.32
26	1564.86	2818.36	1653.82	1362.79	1849.96
30	1628.47	2781.19	1699.49	1157.08	1816.56

Table 18 : Grain yield of IR-36 in Kg/ha from rice plots with various weir heights.

Weir height, cm	Grain yield in Kg/ha during different year			Average
	1993	1994	1995	
6	3265.32	2393.58	1428.79	2362.56
10	2988.67	2359.30	1305.36	2217.78
14	3412.29	2390.75	1480.21	2427.75
18	2962.74	2053.73	1142.80	2053.09
22	3031.90	2599.24	1523.07	2384.74
26	3175.41	2384.75	1294.22	2284.79
30	2954.09	2113.72	1277.08	2114.96

Table 19 : Grain yield of CR-1009 in Kg/ha from rice plots with various weir heights.

Weir heights, cm	Grain yield in Kg/ha during different years			Average
	1993	1994	1995	
6	4250.63	2902.06	2179.61	3110.77
10	4365.87	2433.60	2208.75	3002.74
14	4270.77	2576.44	1668.77	2838.66
18	4112.30	2719.20	2234.46	3021.99
22	4541.71	3050.56	1817.05	3136.44
26	4184.31	2862.04	2153.89	3066.75
30	4192.96	2793.49	2134.18	3040.21



NOTE
ALL DIMENSIONS ARE IN CMS
SCALE - 1:20

FIG. 1 Isometric view of multislot divisor .

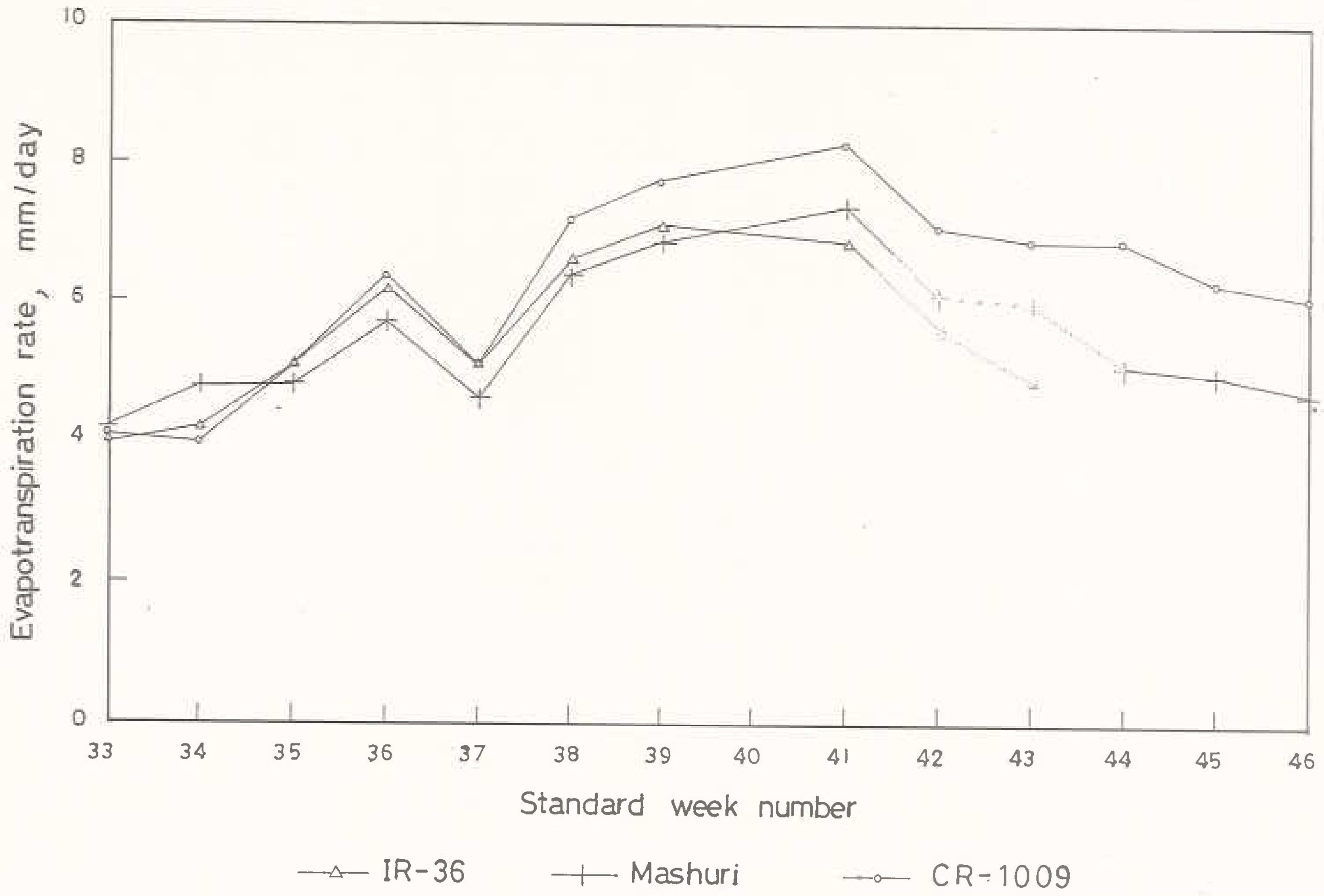


FIG. 2 Evapotranspiration rate in mm/day(average) in the year 1994.

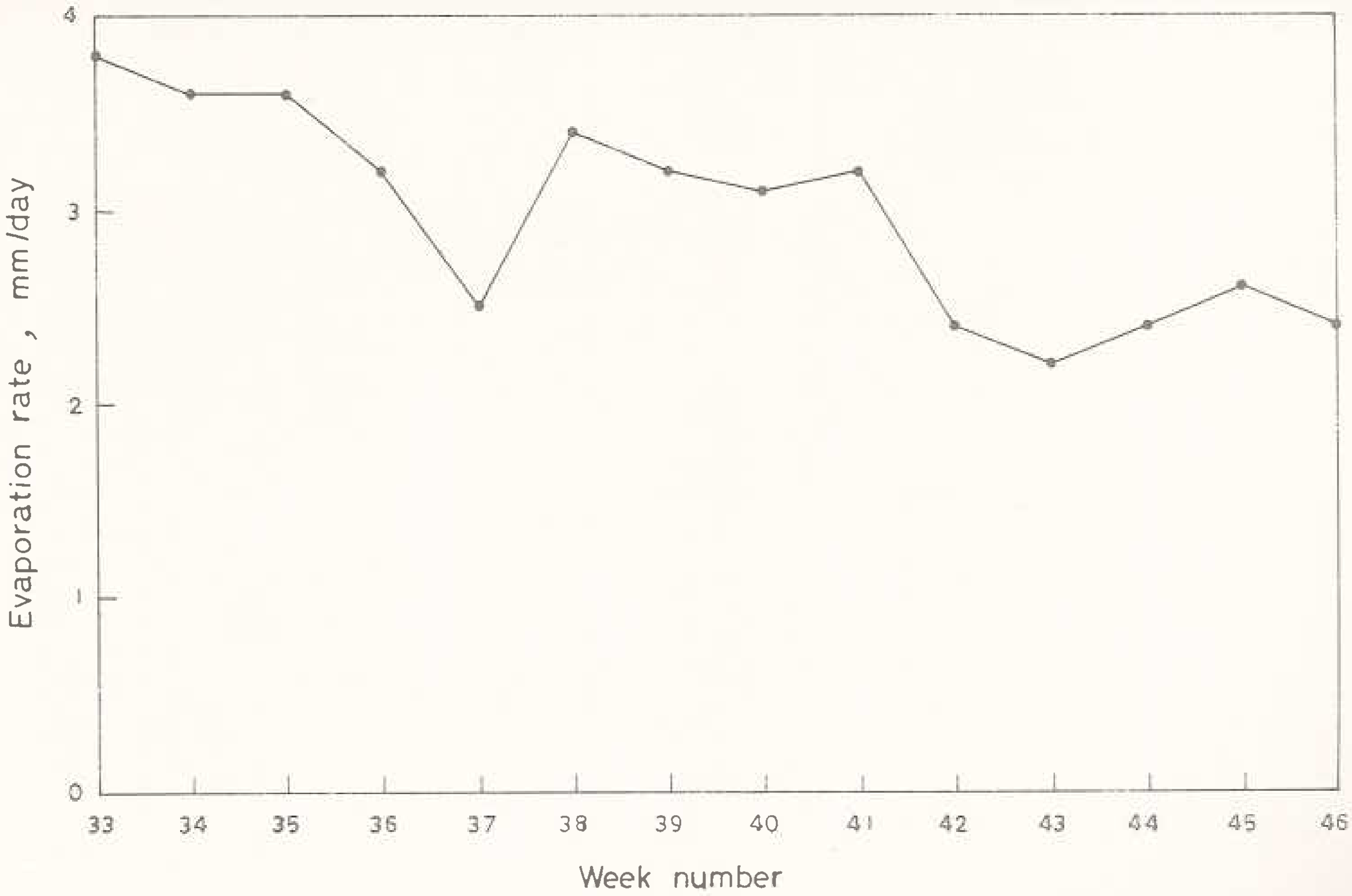


FIG. 3 Evaporation rate from the rice field in mm/day in the year 1994.

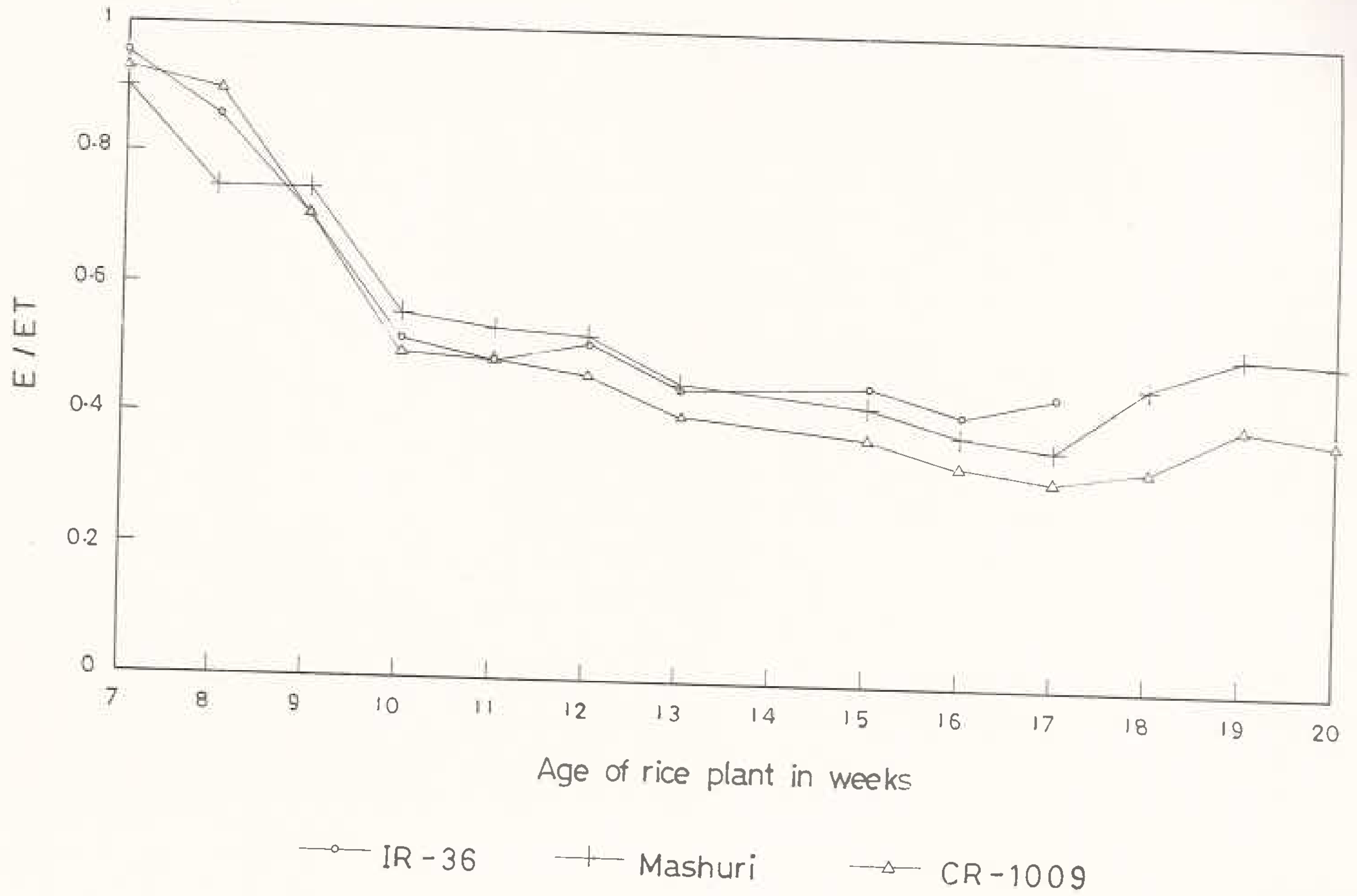


FIG. 4 Ratio of evaporation to evapotranspiration over crop growth period .

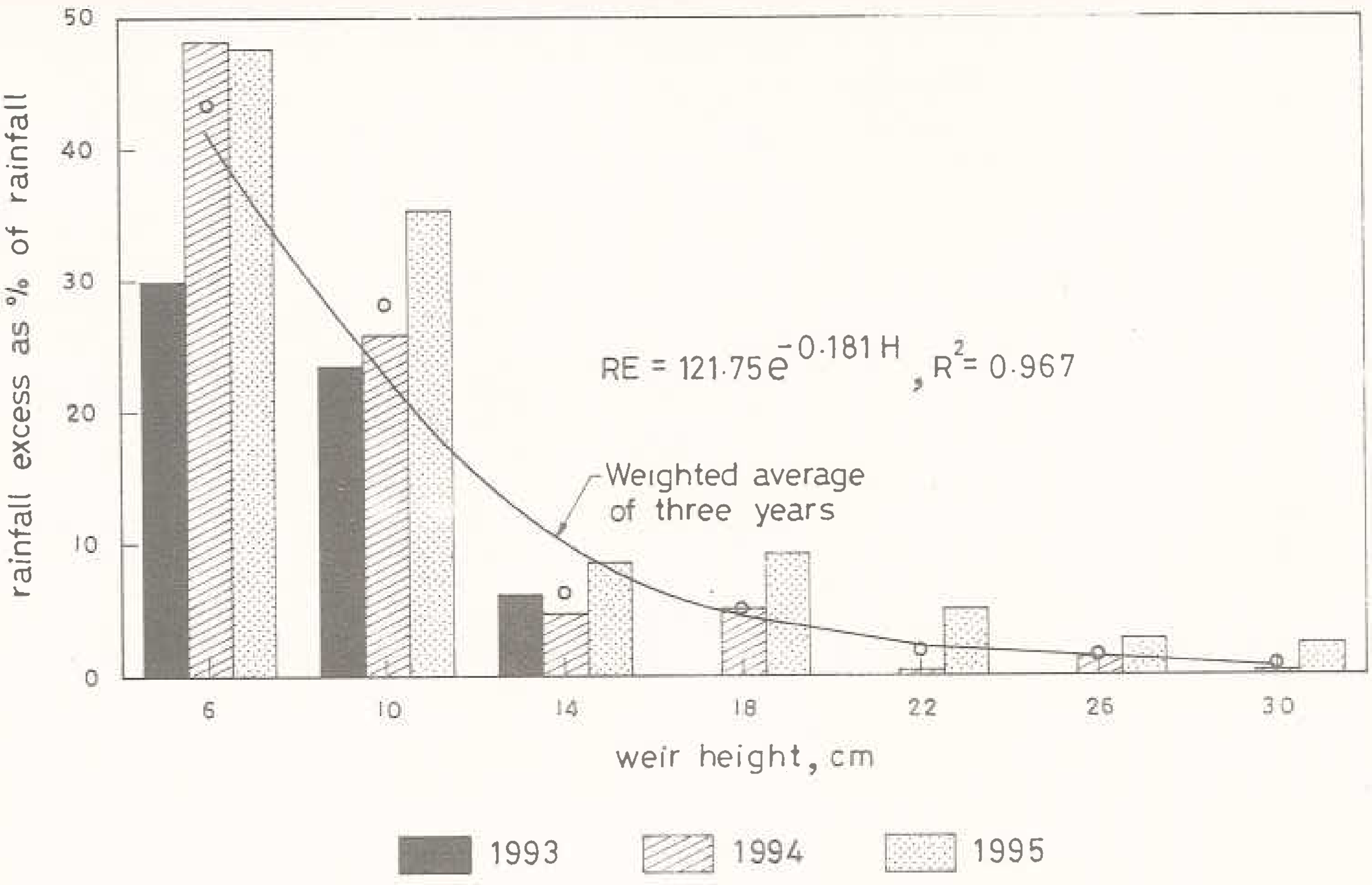


FIG. 5 Rainfall excess as percentage of rainfall from rice fields with various weir heights.

Potassium loss, Kg/ha

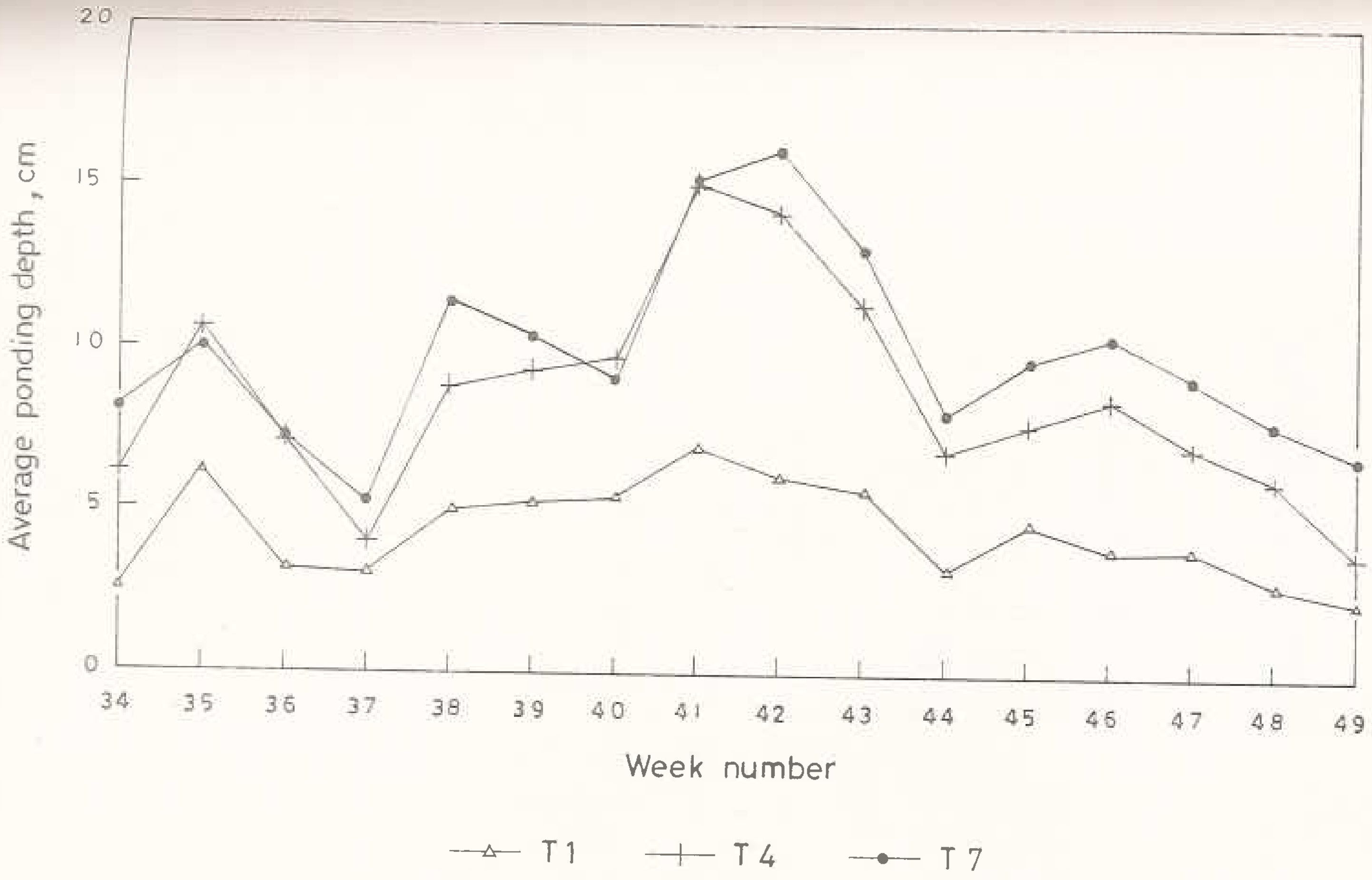


FIG. 6 Hydrograph of ponding in rice fields during 1995.

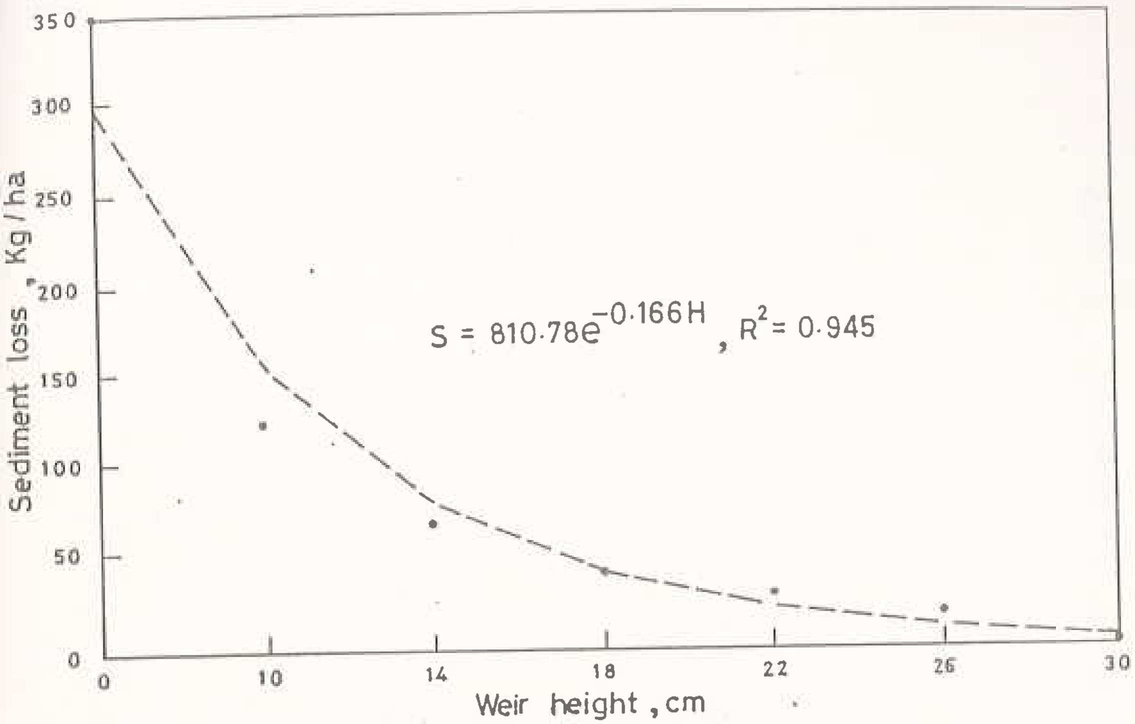


FIG. 7 Loss of sediments in runoff water from rice plots with various weir heights.

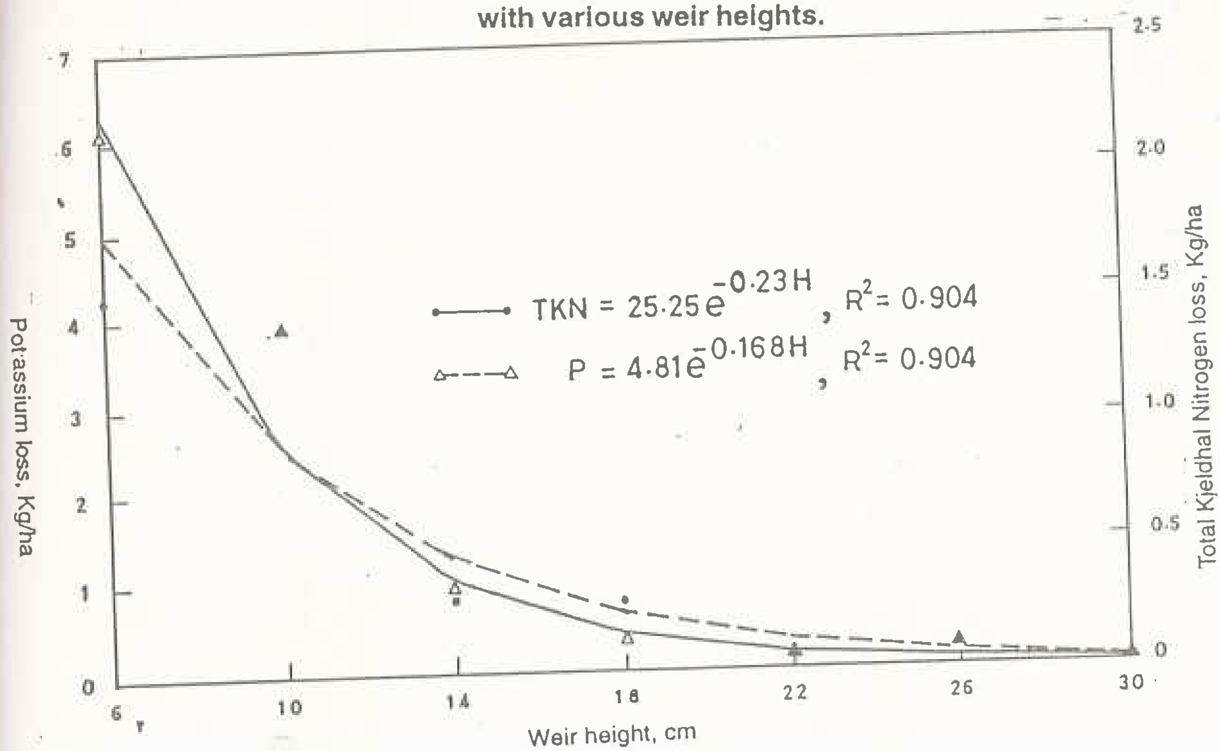


FIG. 8 Loss of TKN and Potassium in runoff water from rice plots with various weir heights.

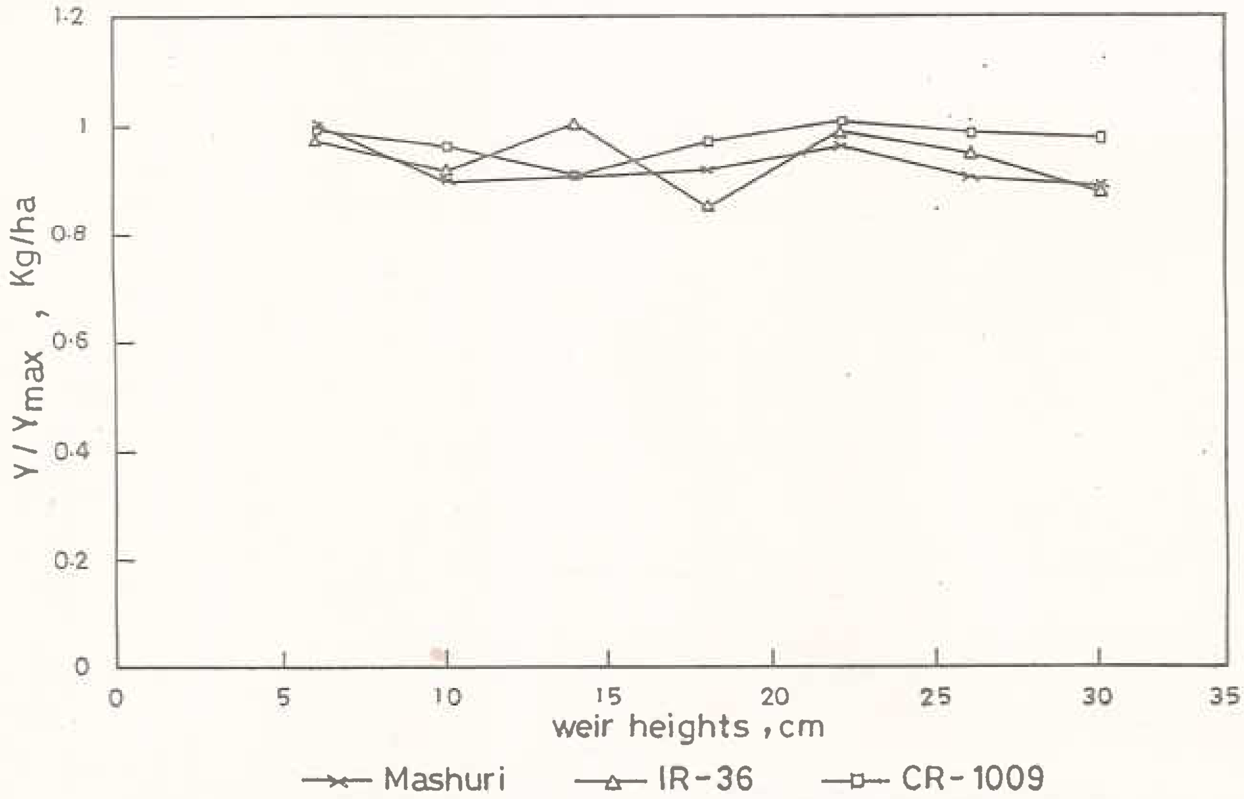


FIG. 11 Dimensionless grain yield at various weir heights (Three years average)

Experimental field with multislot divisor.

Brick massonary rainfall excess collection tanks.

Fibreglass rainfall excess collection tank.

Lysimeters in the experimental plot.