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Crop Response to Methods of Surface Water Distribution

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Abstract: Comparative studies of irrigation methods in relation to crop response was carried out in 1973-1974. Of the two methods of irrigation evaluated, zig-zag furrow method gave well marked yield responses compared to standard furrows. The yields obtained under this method of irrigation was well marked in high moisture response crops. Another feature observed in zig-zag furrows was that the yields in different sections of the furrows are more uniform compared to standard furrows.

1. Introduction

The irrigation methods can be broadly classified into three types:- viz. Surface irrigation, Sub-surface irrigation and Overhead irrigation. Surface irrigation may be either flood irrigation or furrow irrigation. The latter in turn is of the following sub-types:

i. **Standard furrows:** Where the water front advances along the direction of the grade.

ii. **Zig-zag furrows:** Where the water front advances alternately along and against the grade and where the exact geometry of the furrow zig-zags usually tends to depend on the slope, gradient and the spacing of the crop.

iii. **Corrugations:** Where the water front advances down the natural slope in furrows which are invariably less than 200 ft in length.

iv. **Improved corrugations:** Where the water front advances down the natural slope in carefully shaped up furrows along the complete length of the field (even if the field is several miles long) with the use of gated pipes.

The present study is concerned with the standard furrow method and the zig-zag furrow method and is an attempt to evaluate certain aspects of the relative irrigation efficiency of the two methods.

The standard furrow method, which in fact is widespread in Sri Lanka, involves comparative disadvantages such as high labour requirements and low efficiency of water use. It could also contribute to excessive soil erosion and loss of irrigation water through run-off. The zig-zag furrow method, on the other hand, which is less frequent in occurrence in Sri Lanka and, where it occurs, is largely confined to irrigating perennial crops, possesses the advantages of low labour inputs and greater efficiency in water use. The lack of popularity of the zig-zag method in the country is probably due to the fact that it is alien to conventional practices of surface irrigation.

In Sri Lanka, emphasis on irrigated highland cultivation originated with the irrigation projects, developed in the recent past. Uda Walawe, one of such projects, where 63,000 acres of rolling land with natural slopes of 2.5 - 3.5 percent is developed to a grade of 0.5 percent. In this project with the limited availability of water, irrigation was carried out in rotational basis using standard furrows widely. The above combination always results in considerable reduction of crop yield due to improper irrigation and high labour requirements. Therefore the feasibility of adopting zig-zag method, to suit the cultivation of annual crops under the existing "Land System" was examined because of its low labour requirements. This method also facilitates increased water application per unit area of land.

It is the author's contention that the principal significance of the present study lies in the fact that increasing attention is being paid to the production of subsidiary field crops (ie. crops other than paddy) under irrigated conditions in the Dry Zone of Sri Lanka and the consequent need to determine the effects of the different types of irrigation possible upon crop yields. The crops selected for the experiment—Cotton, Chillies and Soyabeans—are among the major crops currently recommended in the programmes of diversification of irrigated agriculture in Sri Lanka.

2. Materials and Methods

The experiments upon which this paper is based, were conducted at the Research Centre, Eraminiyaya, Angunukolapellessa, and were commenced in the Maha season of 1972/73 and were continued in the Yala season of 1973 and 1974.

Results of the study of Maha 1972/73, confined to chilli and cotton provided preliminary evidence that the zig-zag furrow method is superior, in both yield and crop performance, to the standard furrow method. They also indicated that, in the former method, 20 ft furrow segments were superior to longer furrow segments.

Based on this preliminary findings, a more comprehensive comparative study of the two methods was undertaken, once again with chillies and cotton, during the Yala season of 1973, in an experiment laid out in a split-plot design in sub plots of 400 sq ft, replicated three times having methods of irrigation as the main treatment and the three stream sizes, 10 g.p.m., 15 g.p.m. and 20 g.p.m. as the sub treatments (see Figure 7). During the Yala season of 1974, the experiment was repeated with soyabeans. This was also conducted in split-plot design and was replicated 5 times, with variation in the method of irrigation as the main treatment and variation in stream size as the sub-treatment.

In the experiments of 1973 and 1974, the total length of furrow was fixed at 200 ft. The ridges were spaced 2 ft apart with an average height of 8 inches. The furrow segments were 20 ft in length. The crop spacings were 2′ × 1′ for cotton and chilli and 2′ × 3′ for soyabeans.

Soil conditions at the location of the experiments were as follows:

Soil series	:	Ranna Series of Reddish Brown Earths.
Soil structure	:	Sub-angular blocky.
Soil texture	:	Sandy clay loam.
Drainage condition	:	Well drained.
Organic matter	:	Low.
Steady state infiltration rate	:	1.5″ per hour.
Water holding capacity	:	1.5″ per foot.
Grade in feet	:	0.5 percent
Natural slope in feet	:	2.5 percent

The crop management and plant care were carried out in accordance with the standard recommendations of the Department of Agriculture. The irrigation frequencies were fixed at once in four days, five days, and seven days for soyabeans, chillies, and cotton respectively. The irrigation was carried out as per treatment throughout the crop season and the time to irrigate each treatment was recorded. At harvest, the yield data were taken, dividing the full length of the furrow into four sections of 50′ each. This was for the purpose of comparing yields along the different sections of the furrow.

3. Results

The results of the experiments are presented in Tables 1, 2 and 3 and are illustrated graphically in Figures 1 to 5. In overall terms, the results make it clear that the significant variations in the crop responses correlate only with variations of the main treatment (zig-zag method vs standard furrow method) and not with differences in the sub-treatment (ie. stream size).

The data tabulated in Table 1 show that, under the zig-zag furrow method while overall yield levels were significantly higher than under the standard furrow

TABLE 1. Mean yields in pounds per acre and deviation of yields from the mean value in different sections of furrow

Method of Irrigation	*Crop*	*Stream Size*	*Mean Yield*	*SECTION OF FURROW* 1'-50	50'-100'	100'-150'	150'-200'	*Total Deviation*
Zig-zag Furrows	Cotton	10 g.p.m	2624.84	+270.09	—83.85	+42.80	—299.04	±312.89
		15 g.p.m.	2763.92	+348.86	—147.98	—123.16	—77.72	±348.86
		20 g.p.m	2684.09	+274.36	—52.41	—24.39	—197.56	±274.36
Standard Furrows		10 g.p.m	2284.58	—52.20	—106.72	—333.45	+492.37	±492.37
		15 g.p.m	2359.46	+217.03	+299.51	+18.84	—535.38	±535.38
		20 g.p.m	2347.94	+11.34	+20.64	+241.14	—273.12	±273.12
Zig-zag Furrows	Chilli	10 g.p.m	2205.77	—2.81	+56.19	—25.59	—27.79	±56.19
		15 g.p.m	2113.90	+202.46	+141.24	—60.68	—283.02	±343.70
		20 g.p.m	2023.15	—160.53	+63.93	+184.52	—87.92	±248.45
Standard Furrows		10 g.p.m	1537.60	+84.56	+309.76	—65.24	—328.08	±393.32
		15 g.p.m	1505.72	+454.02	—186.51	—285.05	—17.54	±471.56
		20 g.p.m	1199.70	342.11	+7.27	+262.99	+71.85	±342.11
Zig-zag Furrows	Soyabean	10 g.p.m	2161.24	+224.60	—156.54	+20.42	—47.64	±224.60
		15 g.p.m	2654.44	—122.51	—68.06	+176.96	+13.61	±190.57
		20 g.p.m	2314.13	—	—108.88	—81.68	+190.56	±190.56
Standard Furrows		10 g.p.m	1817.27	—183.70	+6.80	+306.22	—129.32	±313.02
		15 g.p.m	1892.14	+40.84	—204.19	—258.64	+421.99	±462.83
		20 g.p.m	2123.55	+27.22	+27.14	—272.25	—217.89	±272.25

L.S.D. for irrigation means
i) Cotton 240.8 lbs/acre
ii) Chilli 496.2 lbs/acre
iii) Soyabean 157.9 lbs/acre

Coefficient of Variation
i) Cotton 9.46%
ii) Chilli 27.7%
iii) Soyabean 22.85%

TABLE 2. Showing the yield under zig-zag method as a percentage of yield under standard method

Method of Irrigation	*Stream Size*	*Crop*	*Mean Yield/Acre in lbs*	*Yield under zig-zag method as % of Yield under standard method*
Standard Furrows	10 g.p.m	Cotton	2284.58	
Zig-zag Furrows	10 g.p.m	Cotton	2624.84	114.90
Standard Furrows	15 g.p.m	Cotton	2359.46	
Zig-zag Furrows	15. g.p.m	Cotton	2763.92	117.10
Standard Furrows	20 g.p.m	Cotton	2347.94	
Zig-zag Furrows	20 g.p.m	Cotton	2684.09	114.30
Standard Furrows	10 g.p.m	Chilli	1537.60	
Zig-zag Furrows	10 g.p.m	Chilli	2205.77	143.40
Standard Furrows	15 g.p.m	Chilli	1505.72	
Zig-zag Furrows	15 g.p.m	Chilli	2113.90	140.30
Standard Furrows	20 g.p.m.	Chilli	1199.70	
Zig-zag Furrows	20 g.p.m	Chilli	2023.15	168.60
Standard Furrows	10 g.p.m	Soyabean	1817.27	
Zig-zag Furrows	10 g.p.m	Soyabean	2661.24	146.20
Standard Furrows	15 g.p.m	Soyabean	1892.14	
Zig-zag Furrows	15 g.p.m	Soyabean	2654.44	140.30
Standard Furrows	20 g.p.m	Soyabean	2123.55	
Zig-zag Furrows	20 g.p.m	Soyabean	2314.18	109.00

TABLE 3. The time of irrigation, total quantity of irrigation water received and the yield/per acre foot of applied water under different treatments

Method of irrigation	*Crop*	*Stream size*	*Time taken to reach the end of furrow in minutes*	*Quantity of water/irrigation/acre in inches*	*Total No. of irrigations*	*Rain fall*	*Total qty. of water received in inches*	*Yield/acre foot or water in lbs.*
Zig-zag furrow	Chilli	10 g.p.m	21	1.01	13	9.36	22.49	98.07
		15 g.p.m	16	1.16	13	9.36	24.44	86.49
		20 g.p.m	15	1.45	13	9.36	28.21	71.70
Standard furrow		10 g.p.m	17.5	0.85	13	9.36	20.41	75.37
		15 g.p.m	13.5	0.98	13	9.36	22.10	68.12
		20 g.p.m	12.5	1.21	13	9.36	25.09	47.79
Zig-zag furrow	Cotton	10 g.p.m	42	2.03	7	9.36	23.57	111.36
		15 g.p.m	31	2.28	7	9.36	25.11	110.07
		20 g.p.m	22	2.13	7	9.36	24.27	110.59
Standard furrow		10 g.p.m	29.5	1.43	7	9.36	19.37	117.94
		15 g.p.m	23.0	1.66	7	9.36	20.98	112.35
		20 g.p.m	16.0	1.54	7	9.36	20.14	116.63
Zig-zag furrow	Soyabean	10 g.p.m	31	1.50	13	5.75	25.25	105.39
		15 g.p.m	29	2.10	13	5.75	33.05	80.19
		20 g.p.m	25	2.42	13	5.75	37.21	62.19
Standard furrow		10 g.p.m	26	1.26	13	5.75	28.37	64.05
		15 g.p.m	19	1.38	13	5.75	23.69	79.87
		20 g.p.m	16	1.54	13	5.75	25.77	82.40

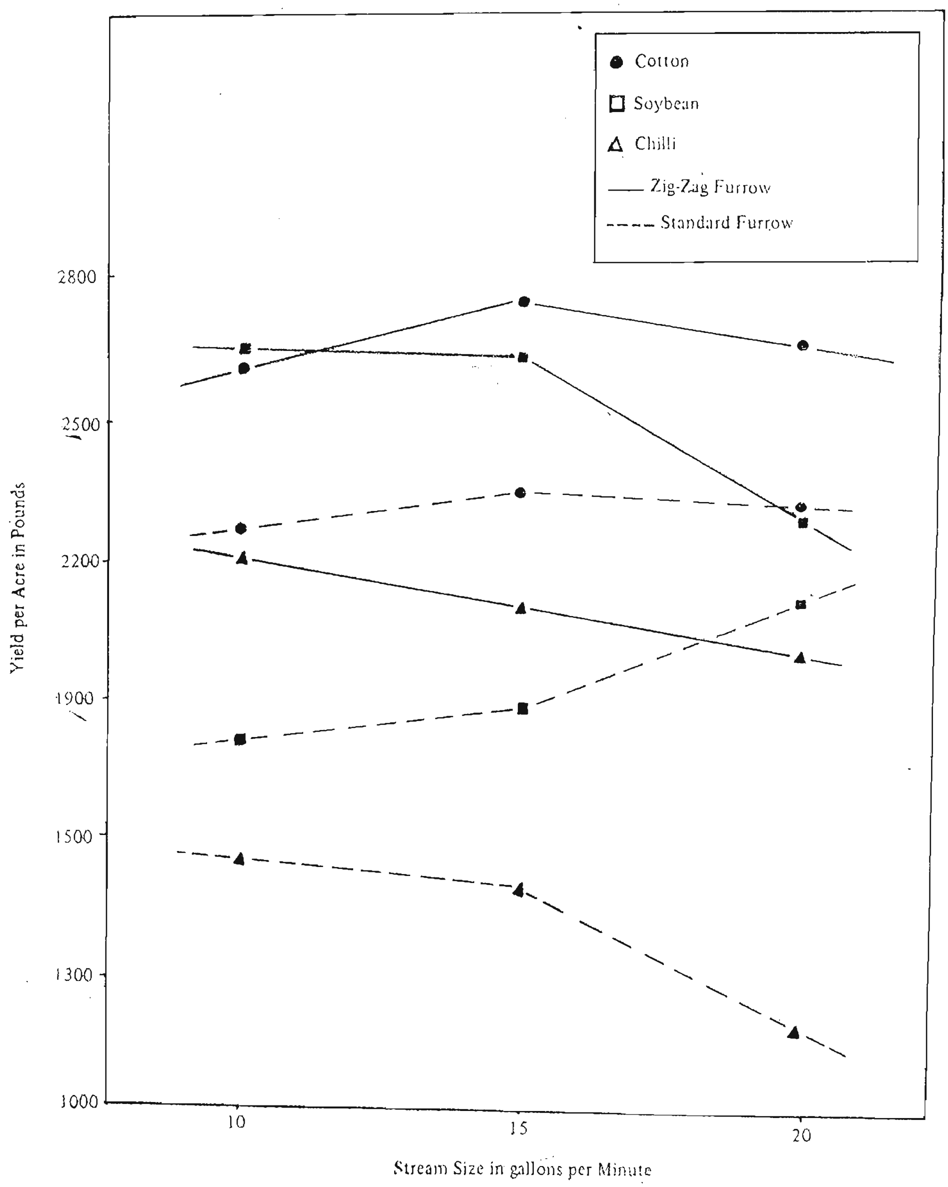

Figure 1. Mean per acre crop yields.

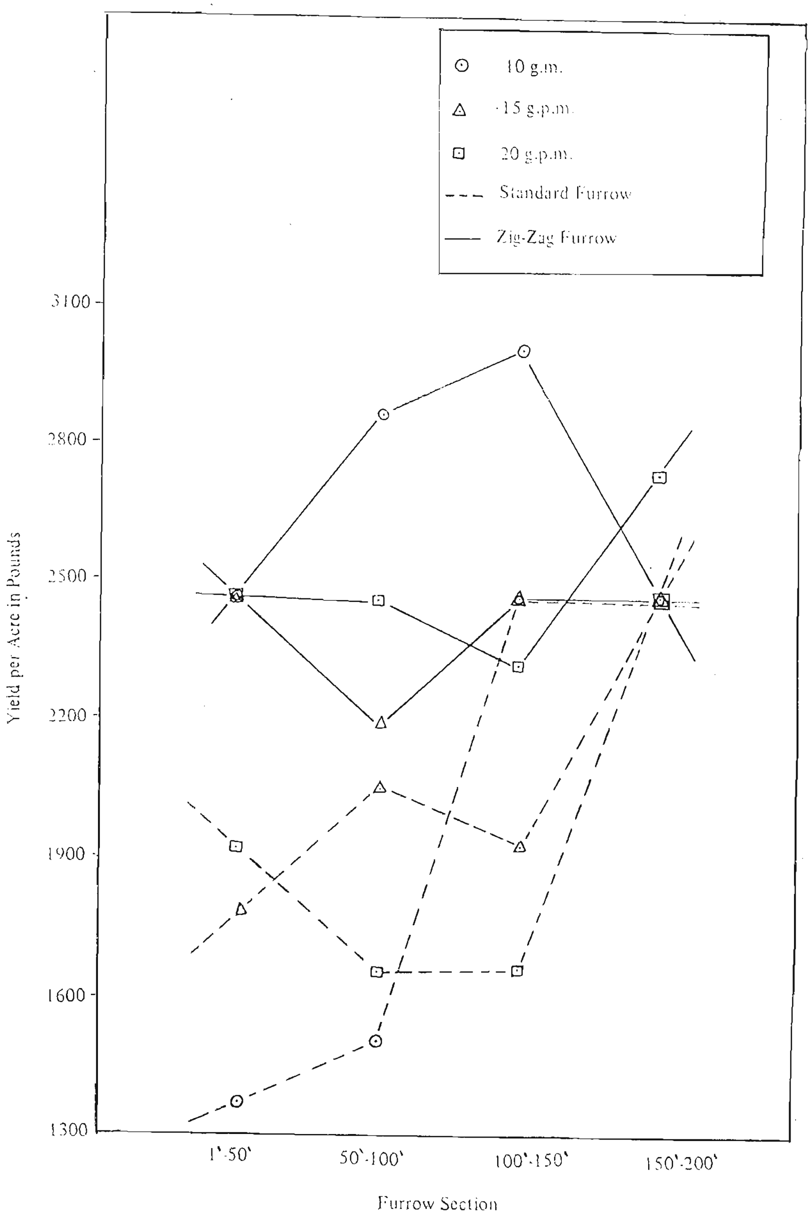

Figure 2. Yield variation in different sections of furrow - Soybean

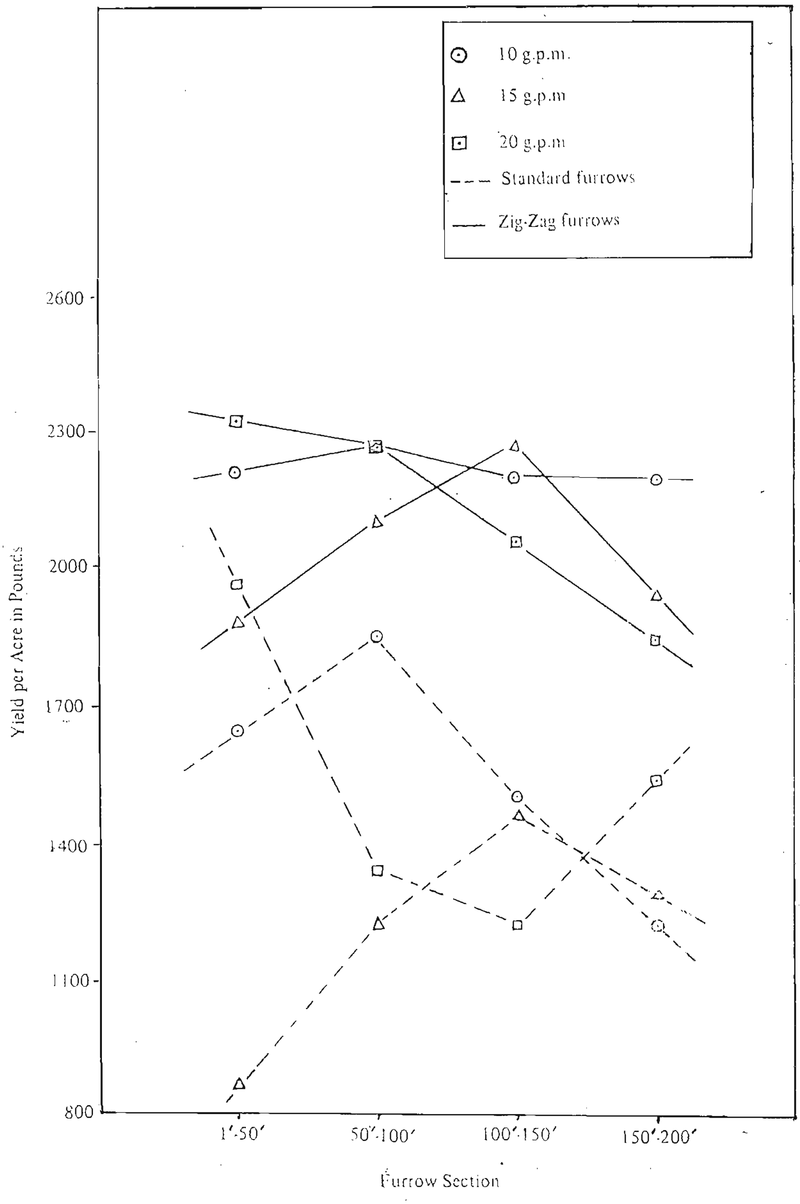

Figure 3 - Yield variation in different sections of furrow Chilli

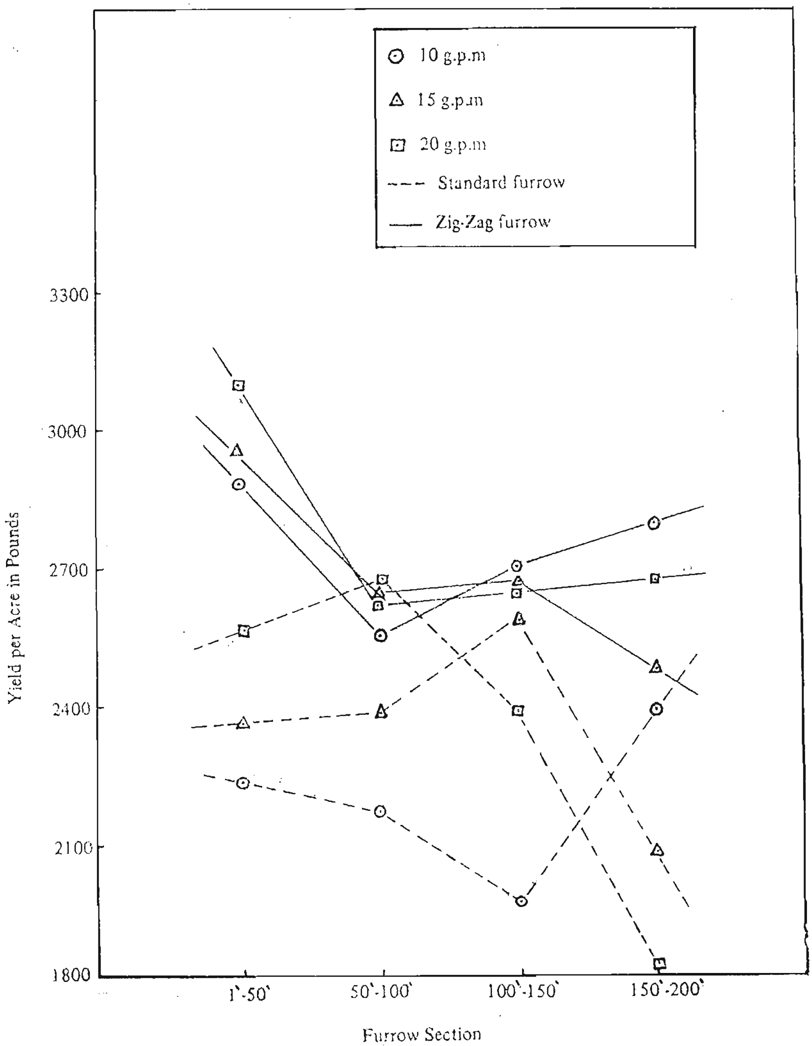

Figure 4 - Yield variation in different sections of furrow - Cotton

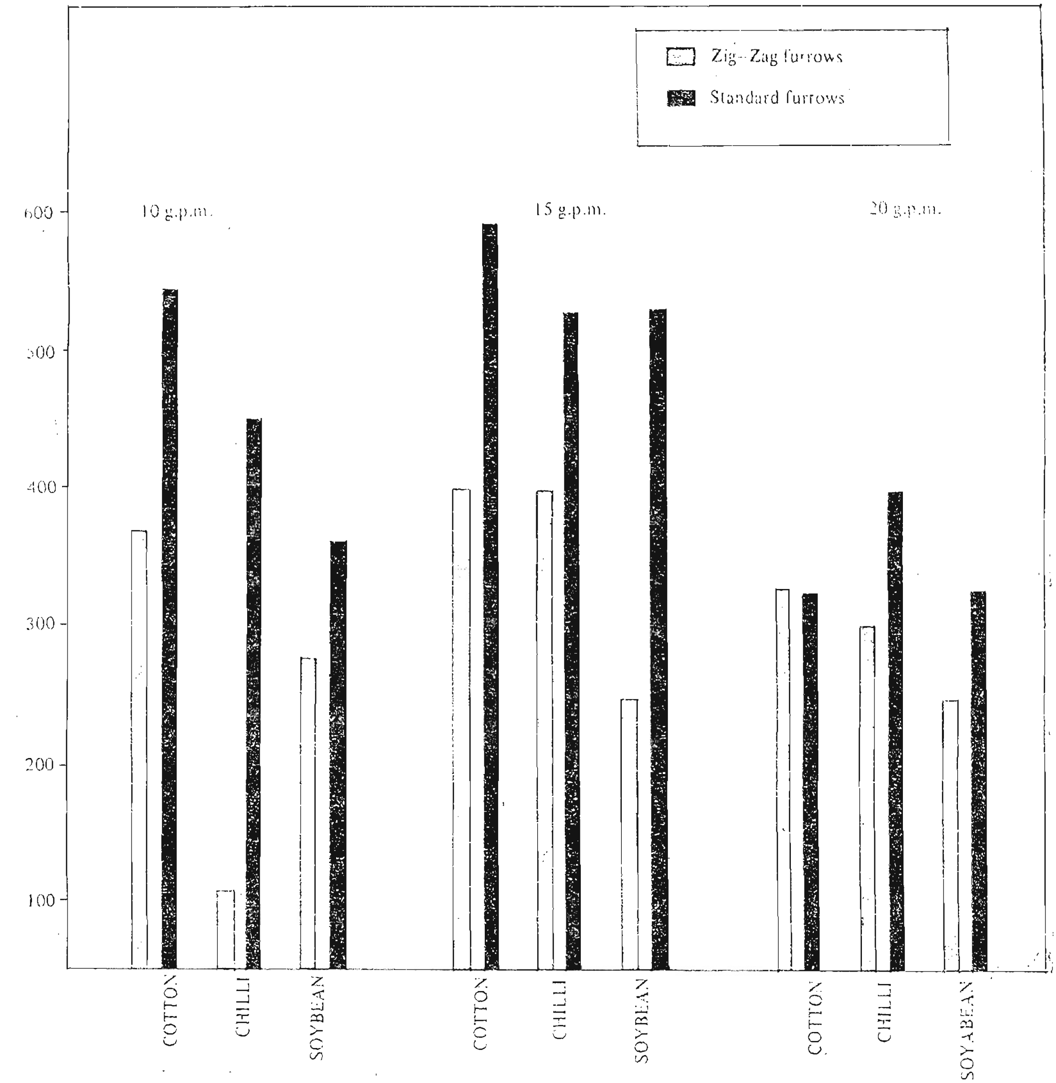

Figure. 5 Total deviations from mean in different treatments

method, the yields obtained in different sections of the furrow were also more uniform (see Figure I). It should further be noted (Columns 5 - 8, Table 1) that the deviations of yield in different segments of the furrow from the mean yield are greater in the standard furrow method than in the zig-zag method.

There is some variation among the different crops in respect of the generalizations made above. For, as Table 2 (which contains data on the mean yields under different treatments and the percentage differences in the yield and the zig-zag furrows and standard furrows) indicate, in the case of the high moisture response crops (chilli and soyabean) the difference in their performance under the two irrigation systems is greater than in the case of the low moisture response crop (cotton).

The total volumes of water received under the different treatments are shown in Table 3. The data here indicate that greater quantities of water could be fed into the furrow through the zig-zag method. This is a contributory cause for the higher yields obtained specially in the case of the high moisture response crops. As shown in the Figure 6 due to the fact that in the zig-zag furrow the water front advances against the grade and fills the inclinations of the furrow in its alternate segments, the volume of water made available for infiltration becomes greater. The exact measurements in this regard are presented in Column 5 of Table 3.

The histogramic representation of Figure 5 substantiates the results referred to above in the sense that the deviations of the yield in the standard furrow are shown to be higher than those of the zig-zag furrow. Apart from this, another interesting feature borne out by the histograms is that, as the stream size is increased, the differences in the performance of the crops under the two methods diminish, thus indicating possibilities of improper irrigation under both methods.

4. Discussions and Conclusions

The results presented above establish that the crop response under the zig-zag furrow method is superior to that of the standard furrow method. The higher yields obtained and the uniformity of the yields along the furrow of the zig-zag method could be attributed either equal contact time between soil and water in every section of the furrow and thus to uniform water infiltration or, alternatively, to uniformity of water distribution which results from the flow of water from high intake areas to low intake areas.

The cause of water front advancement in zig-zag furrows is shown in Figure 6. As stated earlier, in this method the water has to advance against the grade in alternate furrow segments, filling the inclination of the furrow. This process obviously permits a longer contact time and facilitates the infiltration of a greater

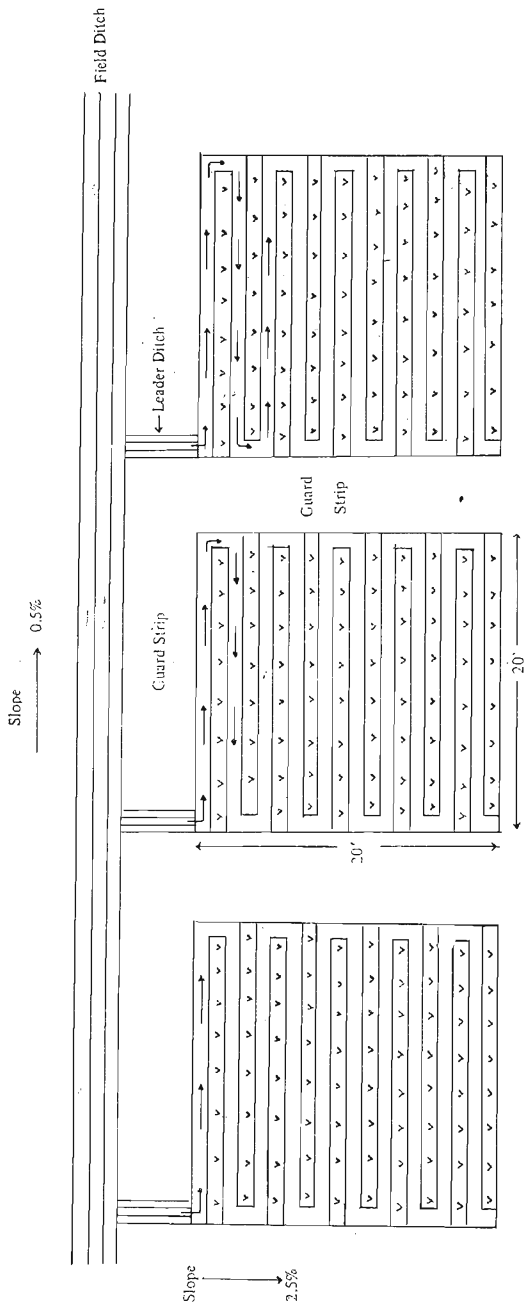

PLATE 1. - Diagrametic representation of water front advancement in Zig-Zag Furrows.

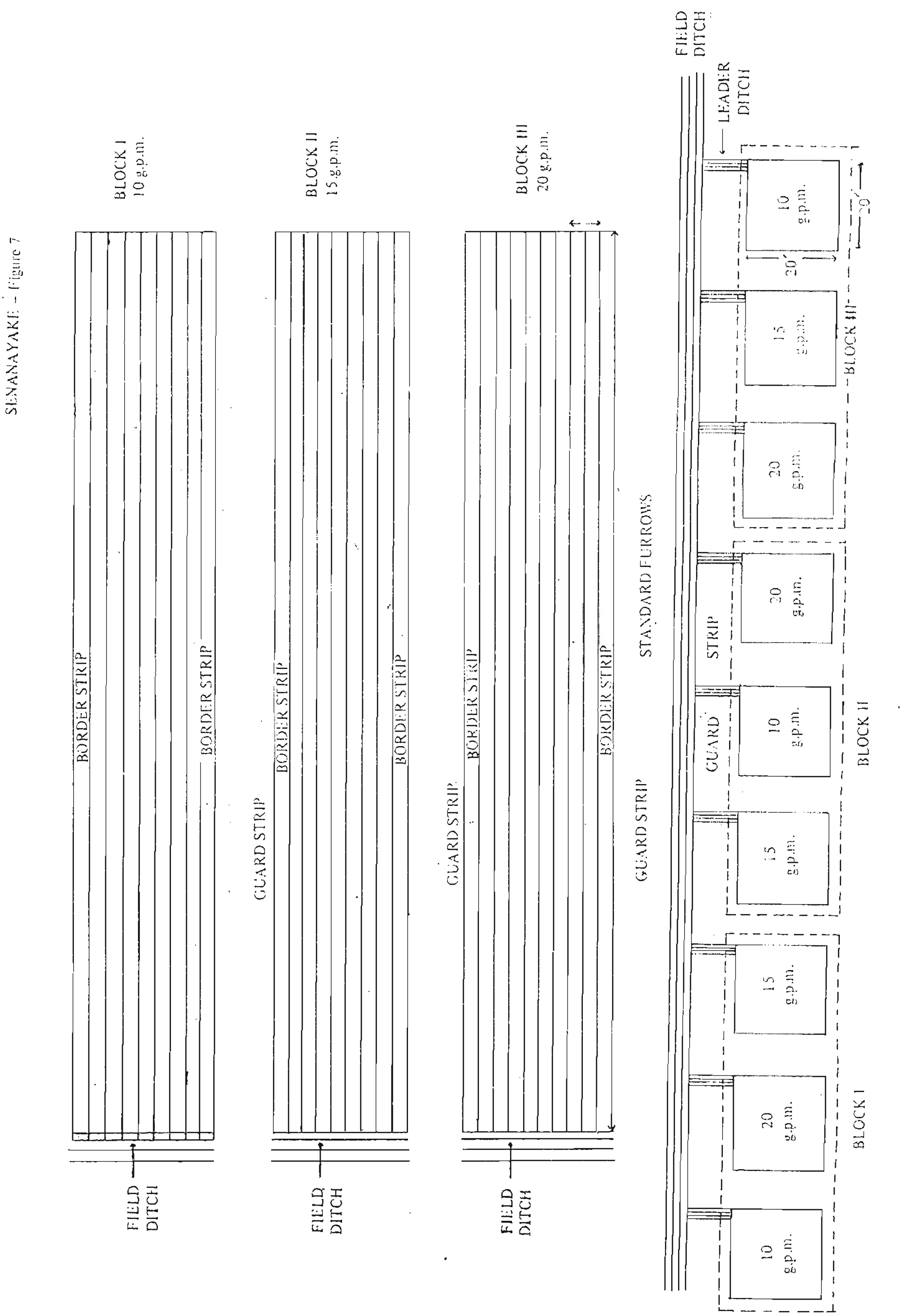

PLATE II. Diagrametic Representation of Field layout of Experiment - Cotton volume of water. In standard furrows, on the other hand, the water front does not change direction once the water is let into the furrow. Furthermore, here the total quantity of water fed into the furrow depends on stream size, length of furrow and grade of the furrow. Normally, the water tends to gush down the grade lowering the infiltration time.

One of the economic implications of adopting the practice of zig-zag furrow method, as mentioned before, is the low labour input inherent to its large scale application. Provided the availability of water is not a limiting factor, irrigation under this method could be carried out simultaneously in a number of zig-zag furrows, either by siphoning from field ditches or by supplying water through buried pipes. The time required for irrigating all zig-zag furrows is the time needed to irrigate one zig-zag furrow, depending, of course, on variables such as stream size and soil conditions. In contrast, under the standard furrow method, water supply to each furrow has to be carried out consecutively, which process obviously requires more labour and more time.

Yet another advantage of the zig-zag furrow method of irrigation is that it facilitates a substantial reduction of uneven irrigation, which in fact, is an error factor even in experimental plots. Water supply in the furrows, either through buried pipes or by siphoning enables uniform irrigation, provided the land preparation is done uniformly. Furthermore, since the zig-zag furrow method permits greater contact time between soil and water, it overcomes the problems of the "sealing effect" (ie. the formation of an impermeable soil crust on the furrow bed) which characteristically inhibits infiltration of water.

The foregoing discussion leads us to the conclusion that in respect of the principal criteria which should be considered in the choice of irrigation technique, the zig-zag furrow is superior to the standard furrow method. The latter is, of course, the more widespread in the cultivation of highland crops, at present, even though it entails a series of problems such as over-irrigation and/or under-irrigation, higher labour inputs and lower infiltration of water to the soil. In practical application by the farmers, the standard furrow method also involves other problems that relate to difficulties of estimating the optimum length of the furrow and the size of the stream. The overall beneficial effect of the zig-zag furrow method of irrigation appears more pronounced in the case of high moisture response crops.

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