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Effect of furrow shape on the field infiltration of crusted silty-loam soil

J. L. Gunton, M.Agr.Sc., Q.D.A.

Summary

In trials conducted at Inglewood, Queensland, the irrigation rate of three furrow shapes was compared. The profile shapes were a normal V, double-V and broad based. The double-V type greatly enhanced infiltration rates under all conditions tested. The advantage of the double-V shape was ascribed to the increased wetted surface area and to the greatly reduced rate of water advance down the furrow.

1. Introduction

The most commonly irrigated soil type of the Macintyre Brook (Inglewood, Queensland) has been described by Isbell (1957) as a silty clay loam. More recent analysis (McAllister and Gunton 1980) identifies these soils as silt loams or loams of alluvial origin. Their high proportion of fine colloidal particles coupled with their inactive clay type, predisposes them to crust formation after wetting. This crust reduces plant emergence and greatly reduces infiltration rates.

Cropping systems currently used in the area (except tobacco and horticultural crops) use mainly short stature row crops. These allow inter-row cultivation between each irrigation which breaks up the surface crust and improves moisture infiltration. This technique is not applicable in other crops, where plant growth may prevent cultivation being carried out at or near a moisture sensitive stage of crop growth, for example, flowering.

It has been found by McAllister and Gunton (1980), Gibson (personal communication) and by local farmer experience that increasing the organic matter of the surface soil will increase the infiltration rates. However, for situations where this is not practicable (for financial, particularly where spray irrigation may be too expensive for large areas, or for other management reasons), it is hypothesized that an increase in the time of contact of water with the soil surface would increase the infiltration rate. This increased time of contact can be achieved by slowing the rate of water advance down the furrow and by increasing the area of contact per unit length of furrow wetted.

In an attempt to test this hypothesis the infiltration rate of three different furrow shapes was measured on graded slopes on a commonly irrigated soil type adjacent to the Macintyre Brook.

2. Materials and methods

A site on silty loam soil at the Queensland Department of Primary Industries Field Station at Inglewood was thoroughly levelled to provide an average slope of 0.12%. The lengths of run were 180 m and 198 m in 1975 and 1977 respectively.

The site was tilled with off-set disc cultivators following winter cereal crops and subsequently kept weed free with a wide foot chisel plough in preparation for soybean crops. These were planted on 23 December 1975 and 6 January 1977. The soybean crop was grown to dry the soil between irrigations and provide row shading effects. Rows were planted 70 cm apart. Six rows were used for each furrow shape, the central four being datum rows. Once the crop had established, the furrow shapes were constructed and then immediately watered (at a slow flow rate) to produce a strong crust.

The furrow shapes were: a normal V; a broad-based furrow; and a double-V (or 'W') shaped furrow. Typical furrow profiles have been drawn in figure 1.

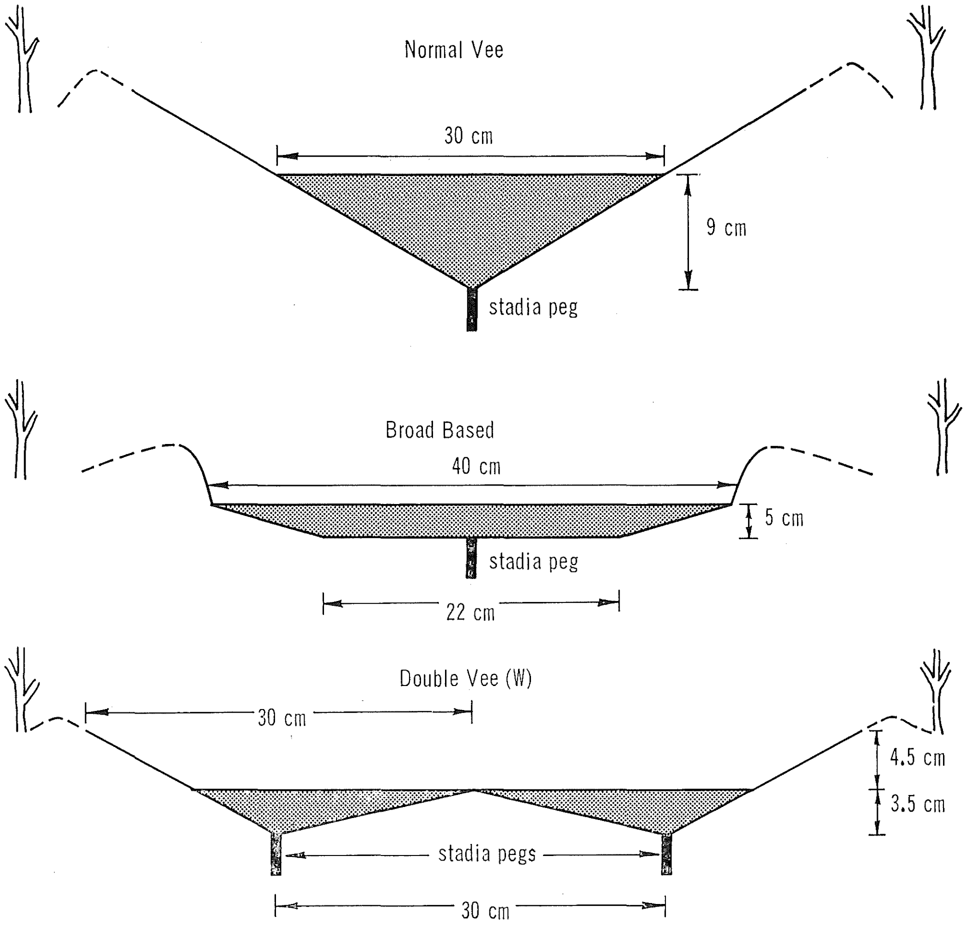

Figure 1. Cross section of furrow shapes (mean water depth shown).

To minimize soaking losses before reaching the test area, water input was measured from an elevated gated pipe immediately in front of the test area. Pipe discharge was regulated to achieve a similar inflow rate for all furrow shapes. Inflow rates were constant throughout the operation.

The method of Finkle and Nir (1960) for measuring volume storage in an irrigated bay was modified (Jobling, personal communication) for furrows. Water storage was calculated from six stations 30 m (1975) or 33 m (1977) apart down the furrows, the first station being at the top of the trial. As the soil is a non-swelling type, small wooden stadia pegs were driven into the base of each furrow at these stations. From these pegs regular water depths (and hence wetted surface area) were taken.

Depth of storage was recorded at all preceding stations when the advance flow reached the next station. Rate of advance was also recorded. Templates were cut for each furrow shape at each station to allow wetted profile to be calculated for any depth measurement.

All inflow rates are given in table 1.

Volume stored was calculated (Finkle and Nir 1960). This was deducted from the volume inflow to derive the volume infiltrated. Accurate drafting techniques were used to derive the final accumulation infiltration rates.

3. Results and discussion

Figures 2 to 5 show the infiltration curves from four separate runs.

From these figures the total infiltration and steady infiltration rates can be calculated. These are presented in table 1.

Two major factors must be considered when assessing the results of these trials. These were low slopes (0.12%) and low inflow rates (approximately 10 L min^{-1}). Practical experience indicates that both these factors are necessary when irrigating broadacre row crops, on typical irrigation soils along the Macintyre Brook.

The trials have clearly demonstrated the superior infiltration rate of the double-V shape compared with the other two shapes, under all conditions tested.

The increased wetted perimeter itself may influence infiltration rate. Sawhney and Parlange (1974) support the concept of wetted area width from their work, where they found vertical infiltration was slowed by lateral infiltration, and that the slowing was inversely proportional to the width of the furrow. Hence the wider the furrow the faster the vertical infiltration. However, the times taken to complete each run (table 1) indicate that the reduction in the rate of advance may be more important in increasing the infiltration rate.

Some measure of this is shown in table 2 where infiltration increases after 2 hours were compared for the different furrow shapes during the four runs. The percentage width increase is also shown.

Table 1. **Effect of three furrow shapes on total infiltration and steady infiltration rates.**

Furrow shape	Crust conditions	Date	Inflow rate (L/min)	Total infiltration (mm) after irrigation time of:			Steady infiltration rate (mm/h)
				1h	2h	3h	
V-shape	wet	11 Feb. 75	13.72	4.1	6.4†	..	3.93*
V-shape	dry	18 Feb. 77	10.79	9.0	10.9	12.8	1.60
V-shape	damp-wet	17 Mar. 77	9.59	2.6	3.7†	..	1.28
V-shape	damp-dry	1 Apr. 77	6.84	4.3	5.8	11.7†	1.39
Broad-based	wet	11 Feb. 75	15.22	4.5	6.7†	..	2.09*
Broad-based	dry	18 Feb. 77	11.57	10.5	13.9	17.0	3.17
Broad-based	damp-wet	17 Mar. 77	9.28	4.2	5.3	..	1.53
Broad-based	damp-dry	1 Apr. 77	8.04	2.7	3.8	5.2†	1.13
Double-V (W)	wet	11 Feb. 75	13.61	6.0	11.5	15.5†	4.95
Double-V (W)	dry	18 Feb. 77	10.05	15.2	18.0	23.7	3.90
Double-V (W)	damp-wet	17 Mar. 77	9.19	6.4	9.6	12.9	3.29
Double-V (W)	damp-dry	1 Apr. 77	7.75	7.7	10.4	12.3	1.74

* extrapolated value.

† short run, uncertain that steady rate had been reached.

Table 2. Increase in furrow width and infiltration rates among the different furrow shapes

Furrow shapes compared	Increase in width (%)	Increase in infiltration (%)			
		11 Feb 75	18 Feb 77	17 Mar 77	1 Apr 77
Broad-based/Vee	36	4.7	27.5	43.2	—ve
Double Vee/Vee	63	79.7	83.5	159.4	79.3
Double Vee/Broad-based	20	71.6	29.5	81.1	173.7

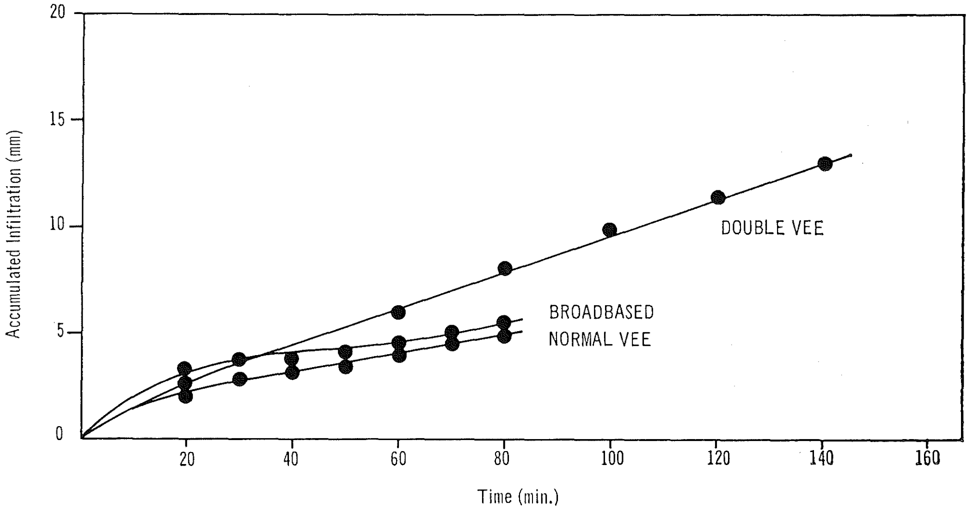

Figure 2. Effect of furrow shape on infiltration, February 1975 (crust wet, first irrigation after crusting).

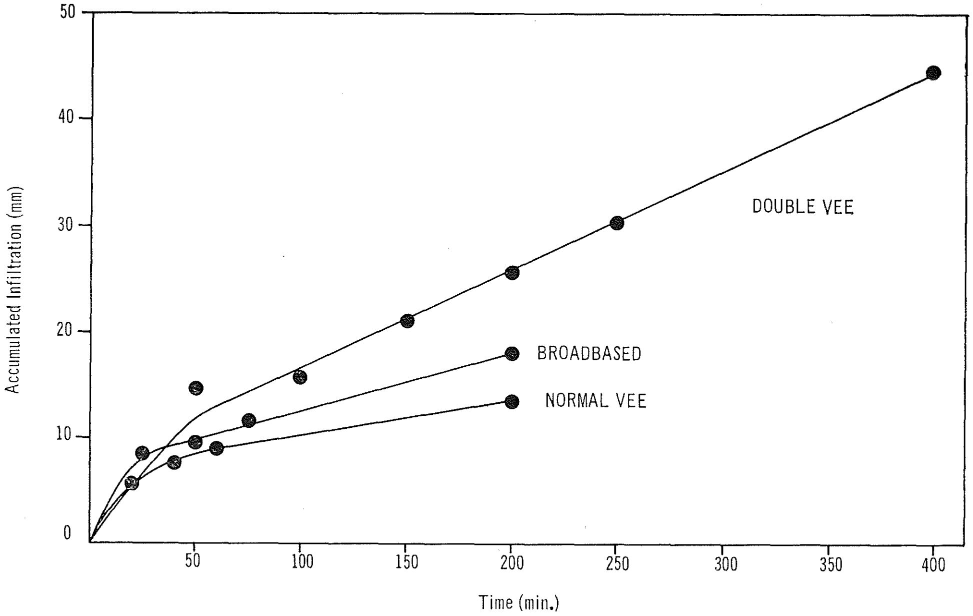

Figure 3. Effect of furrow shape on infiltration, 18 February 1977 (crust dry, first irrigation after crusting).

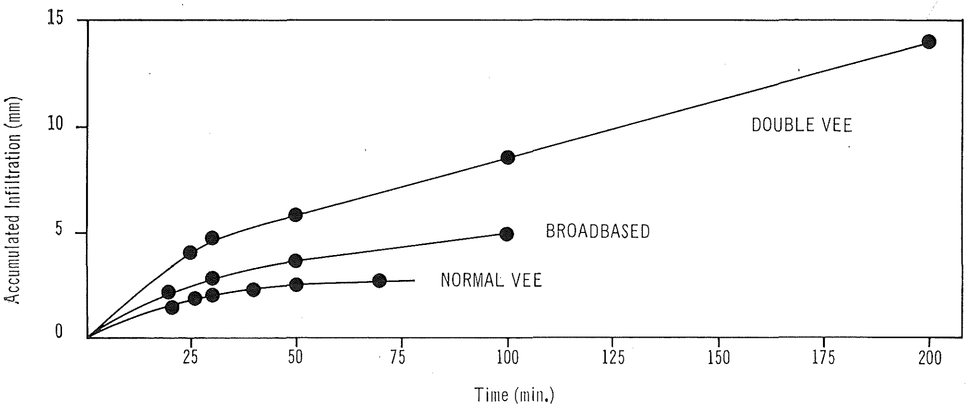

Figure 4. Effect of furrow shape on infiltration, 17 March 1977 (crust damp-wet, second irrigation after crusting).

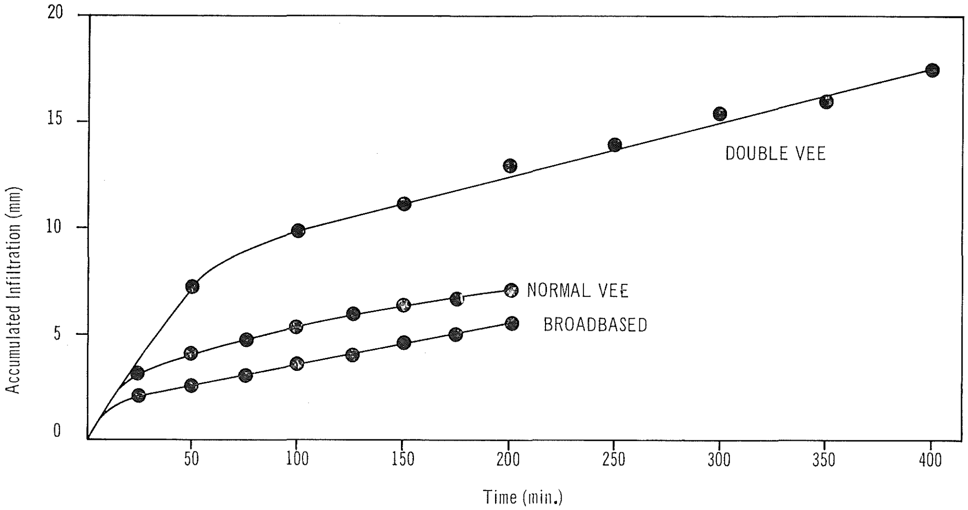

Figure 5. Effect of furrow shape on infiltration, 1 April 1977 (crust damp-dry, third irrigation after crusting).

If wetted profile was the predominant factor influencing infiltration, broad-based furrows should have 36% more infiltration than V-shaped furrows. On two occasions the values were much lower. On 1 April 1977 they fell below the value of the V shape. This was probably due to slumping of the V-furrow walls following three irrigations and several heavy rainfalls. On the second occasion erosion of the broad-based furrow tended to produce more of a V-shape at this late stage of the trial.

On the basis of percentage increase in infiltration of the double-V shaped furrows over the other forms, the infiltration in the double-V furrows was much greater than could be accounted for, by furrow width alone. This suggests that width may not be the most important factor contributing to the increased rates of infiltration recorded for the double-V shaped furrow. The increased infiltration rates seem to have been caused as much by the decreased rate of advance as by the increase of the wetted perimeter. The decreased rate of advance resulted from the restricted flows down the small double-V furrows which are often temporarily dammed by small clods, twigs, and even dead insects. These obstructions cause banking up and re-distribution of water between the double-V furrows and a greatly reduced furrow flow rate occurs. The data suggest that the increase in total accumulated infiltration of the double-V furrow over the broad-based furrow may be as high as 136% (1 April 1977 after 3 hours).

The amount of antecedent moisture may have had some influence on the absolute values achieved as would the 'age' of the furrow. In a field study, however, the effects of these two factors are not easily identified and regardless of these factors the double-V was always superior.

In the management of irrigated crops, the use of double-V shaped furrows during the last possible cultivation (limited by crop height or width) offers some scope for better practices.

The practical advantages of such a system depend on the time taken to infiltrate useful amounts of water over reasonable lengths of furrows. Table 3 indicates the times taken and furrow lengths watered for two infiltrated amounts.

Table 3. Time taken to infiltrate 12.5 mm and 25 mm of water in a double-V shaped furrow from test run results

Date	12.5 mm		25 mm	
	Time (min)	Length (m)	Time (min)	Length (m)
11 Feb 75	141	179	328†	280†
18 Feb 77	42	22	194	98
17 Mar 77	172	162	406†	270†
1 Apr 77	186	101	720†	395†

† extrapolated value

The fastest time (18 February 1977) to infiltrate a given amount of water should be regarded as the more realistic of the values presented and the results of 18 February 1977 are well within the practical capabilities of a furrow irrigation system. The other values have been reduced by antecedent moisture (which usually means irrigation is unnecessary) or by 'ageing' (the result of a number of wetting and drying cycles), and this again indicates that irrigation may not be as necessary for crop completion. By this time it is likely that the crop will be well grown and no further irrigation would be required.

The trial results suggest that irrigation with the double-V furrows after the last possible cultivation would be advantageous under similar conditions to those occurring in these trials, namely, low, even slopes and low inflow rates.

References

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Mr J. L. Gunton is an agronomist with the Queensland Department of Primary Industries, and is station at Hermitage Research Station, Warwick, Q. 4370.