Table 4. Intra and inter cluster D^2 values for the cluster comprising genetic stocks

Clusters	I	II	III	IV	V	VI	VII	VIII
I	3.9							
II	18.2	8.2						
III	11.2	41.3	7.6					
IV	46.9	58.1	73.1	0.0				
V	9.8	24.6	11.0	47.0	5.0			
VI	13.0	17.0	20.3	50.9	9.3	7.5		
VII	13.7	32.7	9.2	61.8	8.6	14.6	4.6	
VIII	25.9	30.7	47.8	37.8	31.4	29.6	25.6	8.0

Table 5. Mean values of the clusters for durum genetic stocks

Characters	I	II	III	IV	V	VI	VII	VIII
Heading days	85.0	81.2	81.9	102.7	86.0	76.4	85.5	95.1
Pant height (cm)	91.5	111.2	86.5	122.1	85.8	110.1	94.8	125.4
Prod. Tillers/plant	5.9	7.7	5.4	4.3	5.6	5.4	5.8	5.7
Grains/ear	48.2	38.0	55.4	34.9	50.9	45.3	52.24	45.3
Grain yield/plant(g)	12.1	14.4	14.6	11.9	15.4	15.9	16.3	12.9
1000 grain Wt. (g)	47.6	48.8	46.3	46.8	52.6	58.6	55.9	58.3
Protein content (%)	13.2	112.4	12.8	14.2	12.1	12.8	113.3	13.2
Sedi. value (ml)	33.6	29.9	30.3	26.3	29.1	28.9	31.2	28.5
Biomass/plant (g)	34.4	36.0	34.8	28.2	34.0	34.8	39.2	41.7
Harvest index	35.2	39.6	42.3	42.2	45.4	45.7	42.5	31.0

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Surge irrigation studies in maize (i) crop response for geometry and on-off timings

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Abstract : Field experiments were carried out from December 1994 to March 1995 at Tamil Nadu Agricultural University to study the impact of maize planting geometry and on – off timings under cost free surge irrigation as compared to continuous flow and basin furrow method of farmers. The quantum of flow was 1.5 lps per furrow and the length of furrow was 150m. The single row planting geometry with higher volume of water consumption influenced the plant height, root volume in surge and continuous flow under two on – off timings of 10 and 15 minutes but not for 20 minutes. Farmers' method recorded increased plant height among the irrigation methods. There is reduction in plant height in sector 5 irrespective of planting geometry, irrigation methods and on – off timings. Single row planting geometry recorded increased cob length as compared to double row planting except on – off timings of 20 minutes. Single row recorded lower yield. Among the sectors, there was a progressive decrease from sector one to four and significant decrease in Sector 5 due to penultimate depression and increase in the last sector due to stagnation. Water saving under single row geometry was ranging from 15-22 per cent.
(Key words : Surge irrigation, Crop response, Geometry)

Among surface irrigation methods, basinfurrow layout with a length of 5-10 m is common for many crops including maize in Tamil Nadu. The area under each basin-furrow accounts for 20-40m. Basin-furrow of short length result in a land loss of 17 to 20 per cent for cultivation.

Manual cutting and closing of openings of basin furrow in the feeder channel involve more labour and turbulent flow into furrows. There is also loss in conveyance and application efficiency. There is an agronomical compulsion to increase the length of the furrow to accomplish land saving, water economy, gentle flow and ease for the labourer without involving additional cost. Surge irrigation delivers water into the furrow by on – off fashion relatively over short interval accomplishing quick advance of water into the distribution over the entire length. It avoids excess water infiltration and run-off on the surface. Surge devices of automated or semiautomated of American origin is cost prohibitive. 'Cost free surge' method was evolved in Tamil Nadu Agricultural University using the inlet pipe technique of Bulgarian farmers (Plovdiv area) who use for continuous irrigation for summer sown field crops. The response of maize (CO.1) for irrigation methods, planting geometry, 'on – off' timings and sectors are discussed in this paper.

Materials and Methods

Experiments were conducted during winter-summer of 1994-95 in a Randomized Block Design. The soil texture was sandy clay loam, medium type of soil for soil moisture behaviour. Field capacity was 22.0 and permanent wilting point was 10.10 per cent. The bulk density was measuring 1.35 g cm^{-3}. Hydraulic conductivity and infiltration rate were measuring 0.45 and 1.30 cm hr^{-1} respectively. The soil was analysing an EC of 0.95 dsm^{-1} and a pH value of 8.40. Irrigation water recorded EC of 0.266 dsm^{-1} and pH value of 8.10.

Cost free surge method has been evolved by involving a head channel of 75 cm diameter to the entire width of the field and inlet pipes (50 x 7.5 cm) made of P.V.C. with lid were buried in the head reach of the furrow (Fig.1 and 2). The furrow size varies according to single row (60 x 20 cm) or double row (120/2=60 x 20 cm) without change in population. There were three irrigation methods viz., continuous, surge and basin furrow methods (10 x 9 M=90m^2). There were three on – off timings viz., 'T on – off' of 10, 15, 20 minutes. The quantum of water per irrigation was 50 mm. All package of practices was adopted. The maize cultivar used for the study was CO.1. The flow rate was 1.5 lps. Irrigation schedule was at 66 mm of cumulative pan evaporation. The following nine treatments were imposed : Single row continuous flow (T_1), single row surge flow T on – off 10 minutes (T_2), single row surge flow T on – off 15 minutes (T_3), single row surge flow T on – off 20 minutes (T_4), Double row continuous flow (T_5), Double row T on – off 10 minutes (T_6), Double row T on – off 15 minutes (T_7), Double row T on – off 20 minutes (T_8) and Basin furrow method of farmer's practice (T_9).

In the present method P.V.C. pipes of 50 cm length and 7.5 cm diameter with lids were used. Further it was made cost free by using scrap aluminium sheets made into a pipe using polythene rope measuring 52 x 6 cm.

Results and Discussion

Plant Height (Table 1)

Under single row, plant height at 90 days was comparable in all the treatments (190.8-191.4 cm), except surge flow with T on – off of 20 minutes (T_4) (168.5 cm). Similar trend was noticed in double row geometry (180.7-181.2 cm) in which the plant height was significantly lesser for T on – off of 20 minutes (T_8) (167.2 cm). Farmers' method recorded a plant height of 190.7 cm. Among the T on – off timings under single row, the plant height was comparable in all treatment except T on – off 20 minutes, [T_4 and T_8]. Out of six sectors there was a progressive decline of plant height. It decreased significantly under T on – off timings of 20 minutes and in the fifth sector (121-125 M). This is attributed to lesser oppurtunity time for infiltration and quick advance of water front and penutimate depression in the fifth sector. The last sector was able to get optimum moisture environment due to stagnation of water with closed furrows. The reduction in plant height under continuous flow was of higher magnitude than surge flow treatment which indicated that the surge flow relatively reduced the spatial variability of infiltration with the length of the run resulting relatively uniform soil moisture content than the continuous flow treatment. Increased plant height in maize under higher level of irrigation was reported by Kuruvilla Varughese (1991).

Root volume (Table 2)

The root volume at 60 days was significantly varying for planting geometry. Under single row the root volume was higher (Table 1) as compared to double row geometry. Farmers' method recorded higher root volume than double row but lesser than single row. On comparing the T on – off timings, there was not much difference between 10 and 15 minutes whereas it was significantly lesser under 20 minutes on – off timings. Among the sectors, there was decrease in root volume from sector one to five and the decline was sharp in the fifth sector and increased

in sector six. The result on root volume revealed that moisture distribution was optimum in the head reach and tail end. Single row furrow is better in terms of moisture status as compared to double row planting T ON=OFF timings of 10 and 15 minutes were favourable and the last but one sector suffered from penultimate depression.

Cob length (Table 3)

Single row planting geometry recorded higher cob length except T on – off 20 minutes (T_4) as compared to double row geometry. Within the single row geometry surge flow T on - off 10 minutes recorded higher cob length (14.66 cm) followed by T on – off 15 minutes (14.56 cm) and significantly lessor cob length under T on – off 20 minutes (12.75 cm). Cob length decreased significantly under fifth sector. Similar trends were seen under double row for different on – off timings and sectors.

Grain yield (Table 4)

Under single row planting geometry all the treatments including continuous flow, surge flow of 10 and 15 minutes recorded higher grain yield (3.7-3.84 t ha^{-1}). The treatment of T on – off of 20 minutes, registered significantly lesser grain yield (2.75 t ha^{-1}). Among the different T on – off timings 10 and 15 minutes recorded higher grain yield except T on – off timing of 20 minutes under double row geometry. In general single row geometry proved to be better than double row geometry for grain yield. Farmers' method of basin furrow gave comparable grain yield with that of continuous flow (T_1), surge flow for 10 and 15 minutes. The treatment of T on – off timings of 20 minutes under single row and double row recorded significantly lesser grain yield.

Comparing the grain yield under different sectors it differed significantly. There was a progressive decrease in grain yield from first sector (0-25m) upto fifth sector (101-125m) and there was an increase in the sixth sector (126-150m). An yield of 3.70 t ha^{-1} was recorded under the fifth sector of double row with the T on – off timings of 20 minutes. A similar trend was recorded for stover yield also (data not furnished). Increased grain and stover yield through adequate irrigation was reported by Lalitha (1994).

Water use efficiency, water requirement and water saving (Table 5)

Water use efficiency was better for the treatment of double row with on – off flow of 10 min. (T_6) followed by double on – off flow for 15 min (T_7). The least was for the treatment of single row continuous flow, total water requirement was highest for single row surge flow of on – off timings of 10 min. (638 cm) followed by farmers' method of basin furrow (587 cm) and single row surge flow with on – off timing of 10 min.

Water requirements was the least for double row with on – off timings of 20 min. (279 cm) indicating the quick water front advance under this treatment. Water saving was the highest for double planting under all on – off timings (10-20 min.) ranging from 50.17-52.47 per cent. Water saving was accounting for 14.82, 21.65, 31.02 for 10, 15 and 20 min on – off timings respectively under single row furrow. Double row furrow registered higher water saving as compared to single row furrow which was related to decrease in grain yield.

The higher yield under single row geometry with T on – off timings of 10, 15 minutes under different sectors is attributed to optimum moisture environment in the soil. Also increased yield level under sector one and gradual decrease upto sector four and an increase in sector six was due to increased volume of water consumed among different irrigation treatments. Farmers' method recorded an yield of 3.8 t ha^{-1}. It is concluded that single row geometry, with T on – off timings of 10-15 minutes are optimum. Furrow length of 150 m with a flow rate of 1.5 lps is also found suitable under the conditions of the experiments. There is progressive decrease in yield due to increase in length which is tolerable except fifth sector due to penultimate depression. There is need to overcome this depression with suitable devices.

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Table 1. Effect of planting geometry, irrigation methods and surge on – off timings on plant height (cm) in different sectors.

Treatment	90 DAS						
	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6	Mean
T_1	211.10	206.27	201.50	164.30	156.60	206.37	191.02
T_2	208.60	204.63	198.10	172.27	164.60	200.20	191.40
T_3	207.97	203.97	197.47	171.70	164.10	208.70	192.32
T_4	189.60	183.70	180.30	141.50	134.80	180.80	168.45
T_5	197.37	191.60	189.97	159.20	155.57	191.77	180.91
T_6	193.90	192.43	189.90	163.07	159.47	188.43	181.20
T_7	193.33	191.90	189.40	162.63	159.00	187.93	180.70
T_8	188.10	182.23	178.90	140.43	133.80	179.70	167.19
T_9				190.7			
Mean	197.85	194.16	190.69	162.87	157.63	192.73	182.66
		SEd			CD		
Main		3.590			7.70		
Sub plot		1.840			3.70		
M x S		3.610			7.74		
S x M		0.449			0.894		

T.1. Single row continuous flow	Sector 1	0-25 M
T.2. Single row surge flow + on-off 10 min	Sector 2	26-50 M
T.3. Single row surge flow + on-off 15 min	Sector 3	51-75 M
T.4. Single row surge flow + on-off 20 min	Sector 4	76-100 M
T.5. Double row surge flow	Sector 5	101-125 M
T.6. Double row surge flow + on-off 10 min	Sector 6	126-150 M
T.7. Double row surge flow + on-off 15 min	DAS : Days after sowing	
T.8. Double row surge flow + on-off 20 min		
T.9. Farmers' method		

Table 2. Effect of planting geometry, irrigation methods and surge on – off timings on root volume (cc) in different sectors

Treatment	60 DAS						
	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6	Mean
T_1	60.22	59.07	57.63	48038	47039	57091	55.1
T_2	58.36	58.58	57.86	49.30	48.04	57.26	54.9
T_3	58.25	58.47	57.76	47.54	47.95	57.16	54.52
T_4	54.58	53.65	51.70	41.53	40.48	50.77	48.78
T_5	57.13	55.86	54.29	44.98	43.43	54.44	51.69
T_6	55.58	55.47	54.75	45.59	44.98	53.44	51.64
T_7	55.36	55.61	54.54	45.74	44.81	53.07	51.64
T_8	53.63	52.72	50.80	40.74	39.78	49.89	47.93
T_9				55.75			
Mean	56.54	56.13	55.01	46.62	45.85	54.41	52.43
		SEd			CD		
Main plot		1.225			2.628		
Sub plot		0.133			0.264		
M x S		1.272			2.710		
S x M		0.375			0.748		

DAS - Days after sowing

Table 3. Effect of planting geometry, irrigation methods and surge ON/OFF timings on cob length in different sectors.

Treatment	Cob length (cm)						
	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6	Mean
T_1	15.24	15.01	14.79	13.76	13.34	14.95	14.52
T_2	14.97	15.01	14.97	14.14	13.78	15.06	14.66
T_3	14.88	14.92	14.85	14.05	13.69	14.97	14.56
T_4	13.64	13.26	13.15	11.82	11.61	13.01	12.75
T_5	14.40	14.16	13.95	12.90	12.53	13.96	13.65
T_6	14.17	14.06	14.02	13.17	12.76	14.13	13.72
T_7	14.38	14.16	13.99	13.14	12.74	14.10	13.75
T_8	13.80	13.42	43.30	12.13	11.74	13.16	12.93
T_9				14.60			
Mean	14.45	14.29	14.18	13.3	12.98	14.22	13.90
		SEd			CD		
Main plot		0.135			0.676		
Sub plot		0.024			0.084		
M x S		0.321			0.687		
S x M		0.069			0.137		

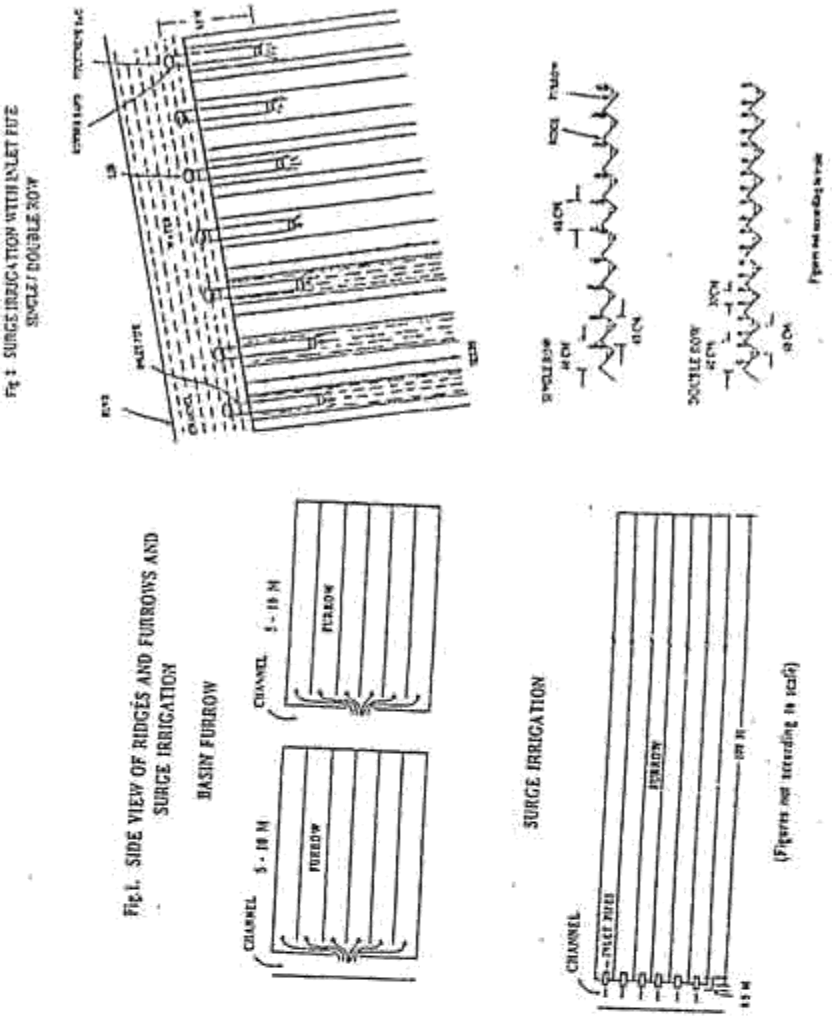
Table 4. Effect of planting geometry, irrigation methods and surge on–off timings on grain yield (t ha^{-1}) in different sectors.

Treatment	Grain yield (t ha^{-1})						
	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6	Mean
T_1	4.08	3.96	3.86	3.24	3.19	3.88	3.70
T_2	4.09	4.05	4.01	3.53	3.35	4.02	3.84
T_3	4.00	3.97	3.93	3.46	3.27	3.93	3.76
T_4	3.13	3.02	2.94	2.34	2.15	2.91	2.75
T_5	3.86	3.76	3.65	2.96	2.76	3.69	3.45
T_6	3.76	3.72	3.68	3.13	2.95	3.62	3.48
T_7	3.78	3.74	3.71	3.15	2.98	3.64	3.50
T_8	2.91	2.80	2.73	2.17	1.99	2.70	2.55
T_9				3.81			
Mean	3.67	3.61	3.56	3.07	2.91	3.54	3.39
		SEd			CD		
Main plot		0.076			0.164		
Sub plot		0.003			0.006		
M x S		0.077			0.165		
S x M		0.009			0.017		

Table 5. Effect of planting geometry, irrigation methods and surge on–off timings on total water requirement, water use efficiency and water saving.

Treatment	WUE (kg ha^{-1} mm^{-1})	Total water requirement (mm)	Water saved over farmers method (per cent)
T_1	6.03	631.8	-7.60
T_2	7.58	500.0	14.82
T_3	8.18	459.9	21.65
T_4	5.98	404.9	31.02
T_5	8.94	386.1	34.22
T_6	12.0	290.0	50.60
T_7	11.97	292.5	50.17
T_8	9.14	276.0	52.47
T_9	6.47	587.0	------

* Data statistically not analysed



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Surge irrigation studies in maize (ii) water front advance in relation to geometry and T on – off timings

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Abstract : Water front advance in relation to crop geometry T on-off timing under continuous and surge flow was studied in Tamil Nadu Agricultural University. The soil was sandy clay loam. The slope was 0.5 per cent. Cost free surge layout was adopted using inlet pipes (50 x 7.5 cm) and manually operated. Water front advance took more time for continuous irrigation as compared to surge flow. Among the crop geometry, water front advance was faster under double row as compared to single row. Out of three T on-off timings there was not much difference in water front advance between 10 and 15 minutes. Water front advance was faster in 20 minutes. Surge irrigation in maize with single crop row geometry and T on-off timings of 10-15 with a flow rate 1.5 lps is optimum from the point of view of water front advance.
(Key words : Surge irrigation, Water front advance, Geometry)

Surge irrigation is the delivery of water into the furrow in an alternate fashion relatively over short span of interval so as to enable the particle displacement, deposition, reorientation and surface sealing to provide increased opportunity time for water front advance and to avoid excess infiltration