CHAPTER - 5

RESULTS, ANALYSIS, CONCLUSIONS AND RECOMMENDATIONS

5.1 General

To determine head loss through laterals and outlets of ITK MIS, laboratory experiments were conducted. Based on the experimental data regression equations were developed. F factor was determined for ITK MIS for 20 mm diameter of lateral. The relationship between inlet pressure & microtube discharge and length of microtube was developed to determine length of microtube and is presented in this chapter.

To determine the cost effectiveness and yield response of MIS and ITK MIS, summer groundnut and cauliflower were raised on these systems. After obtaining yield data, Internal Rate of Return (IRR) was calculated for the combinations of crop spacings, irrigation depths and irrigation systems for summer groundnut and cauliflower.

Internal rate of return for the years 2005, 2006 and 2007 are discussed in this chapter. Analysis of variance is carried out to analyze the effects of crop spacings, irrigation depths and irrigation systems on yield and IRR, and are presented here.

5.2 Results

Results of indoor ITK MIS laboratory work and field experimental work carried out are either presented earlier in Chapter 4 or presented here.

5.2.1 Indoor ITK MIS laboratory work

Friction head loss in ITK MIS

The head losses through length segments of laterals and minor head losses at outlets were determined and presented in chapter 4 along with the data Tables.

Tables 4.11 to 4.28 contain data and analysis for 12 mm lateral – 4 mm, 5 mm, & 6 mm diameter and 0.15 m, 0.30 m, 0.45 m, 0.60 m, 0.75 m, & 0.90 m long polytube respectively (In each length of polytube 27 tables of 1 MT 1.0-0.30, 1 MT 1.0-0.60, 1 MT 1.0-0.90, 1 MT 1.2-0.30, 1 MT 1.2-0.60, 1 MT 1.2- 0.90, 1 MT 1.5-0.30, 1 MT 1.5-0.60, 1 MT 1.5-0.90 and similarly for 2 MT, 3 MT and 4 MT) and are given in enclosed DVD.

N.B. MT- Microtube

1 MT 1.0-0.30 stands for 1 microtube having 1 mm diameter and 0.30 m length...

4 MT 1.5 - 0.90 stands for 4 microtubes having 1.5 mm diameter and 0.90 m length....

Tables 4.29 to 4.46 contain data and analysis for 16 mm lateral – 4 mm, 5 mm, & 6 mm diameter and 0.15 m, 0.30 m, 0.45 m, 0.60 m, 0.75 m, & 0.90 m long polytube respectively and are given in enclosed DVD.

Tables 4.47 to 4.70 contain data and analysis for 20 mm lateral – 4 mm, 5 mm, 6 mm, & 7 mm diameter and 0.15 m, 0.30 m, 0.45 m, 0.60 m, 0.75 m, & 0.90 m long polytube respectively and are given in enclosed DVD.

Minor head loss at outlets by regression analysis

Minor head loss at all eight outlets are determined for 20 mm, 16 mm, & 12 mm diameter of lateral. Regression equations are developed as per no. of microtubes attached to micromanifold for each lateral.

Table 5.1 gives regression equations for minor head loss at outlets of 20 mm lateral for 1 microtube.

Tables 5.2, 5.3, & 5.4 give regression equations for minor head loss at outlets of 20 mm lateral for 2, 3, & 4 microtubes respectively and are given in enclosed DVD.

Table 5.5 gives regression equations for minor head loss at outlets of 16 mm lateral for 1 microtube.

Tables 5.6 & 5.7 give regression equations for minor head loss at outlets of 16 mm lateral for 2 & 3 microtubes respectively and are given in enclosed DVD.

Table 5.8 gives regression equations for minor head loss at outlets of 12 mm lateral for 1 microtube.

Tables 5.9 & 5.10 give regression equations for minor head loss at outlets of 12 mm lateral for 2 & 3 microtubes respectively and are given in enclosed DVD.

Head loss through polytubes

Table 5.11 gives regression equations to determine head loss through polytube attached to 20 mm lateral at various outlets for 1 microtubes attached with micromanifold.

Tables 5.12, 5.13 & 5.14 give regression equations to determine head loss through polytube attached to 20 mm lateral at various outlets for 2, 3 & 4 microtubes attached with micromanifold respectively and are given in enclosed DVD.

Table 5.15 contains regression equations to determine head loss through polytube attached to 16 mm lateral at various outlets for 1 microtube attached with micromanifold.

Tables 5.16 & 5.17 contain regression equations to determine head loss through polytube attached to 16 mm lateral at various outlets for 2, 3 microtubes attached with micromanifold respectively and are given in enclosed DVD.

Table 5.18 contains regression equations to determine head loss through polytube attached to 12 mm lateral at various outlets for 1 microtube attached with micromanifold.

Tables 5.19 & 5.20 contain regression equations to determine head loss through polytube attached to 12 mm lateral at various outlets for 2 & 3 microtubes attached with micromanifold respectively and are given in enclosed DVD.

Notations used in regression equations to determine minor head loss are as follows:

hf_i^* = Head loss at outlet on lateral, m

Q_i = Discharge through various length segments of lateral, m^3/sec

q_i = Discharge measured at the end of micro tube in each set, m^3/sec

p_i = Pressure measured on both sides of polytube on lateral, mwc

Notations used in regression equations to determine head loss through polytube are as follows:

hp_i = Head loss through polytube, m

dp_i = Diameter of polytube, mm

lp_j = Length of polytube, m

Table 5.1: Regression Equations for Minor Head Loss at Outlets of 20 mm Lateral for 1 Microtube

Outlet No.	Model for determining minor head losses	Summary of preparation and validation of model		
		Particular	Model	
			Preparation	Validation
1	$hf_1 = 23708.668q_1 + 456.509Q_1 + 0.008p_1 - 0.270$	D	1.02	1.06
		R^2	0.65	0.66
		r	0.81	0.81
		R.M.S.E.	0.11	0.11
2	$hf_2 = 21600.82q_2 + 326.139Q_2 - 0.00447p_3 - 0.121$	D	0.98	0.99
		R^2	0.64	0.62
		r	0.80	0.78
		R.M.S.E.	0.08	0.08
3	$hf_3 = 16860.59q_3 + 299.050Q_3 + 0.00282p_5 - 0.111$	D	1.02	1.01
		R^2	0.51	0.51
		r	0.72	0.71
		R.M.S.E.	0.09	0.09
4	$hf_4 = 4287.696q_4 + 104.3026Q_4 - 0.00740p_7 + 0.085$	D	1.00	0.99
		R^2	0.34	0.36
		r	0.58	0.60
		R.M.S.E.	0.06	0.06
5	$hf_5 = 3205.918q_5 + 232.99Q_5 - 0.000933p_9 - 0.0263$	D	1.01	1.01
		R^2	0.60	0.59
		r	0.78	0.77
		R.M.S.E.	0.05	0.05
6	$hf_6 = 459.340q_6 + 246.007Q_6 - 0.000784p_{11} - 0.0239$	D	1.01	1.02
		R^2	0.43	0.45
		r	0.65	0.67
		R.M.S.E.	0.07	0.07
7	$hf_7 = 13952.54q_7 + 180.51Q_7 - 0.00187p_{13} - 0.09123$	D	1.34	1.10
		R^2	0.55	0.55
		r	0.74	0.74
		R.M.S.E.	0.05	0.05
8	$hf_8 = 13982.48q_8 + 172.65Q_8 - 0.00122p_{15} - 0.0895$	D	1.21	1.14
		R^2	0.45	0.47
		r	0.67	0.69
		R.M.S.E.	0.06	0.06

Table 5.5: Regression Equations for Minor Head Loss at Outlets of 16 mm Lateral for 1 Microtube

Outlet No.	Model for determining minor head losses	Summary of preparation and validation of model		
		Particular	Model	
			Preparation	Validation
1	$hf_1 = -\ 1661.25q_1 - 22955.24Q_1 + 0.1791p_1 + 0.722$	D	1.03	1.03
		R^2	0.43	0.42
		r	0.66	0.65
		R.M.S.E.	0.09	0.09
2	$hf_2 = -1082.5q_2 - 38356.4Q_2 + 2.86E\text{-}01p_3 + 1.214$	D	1.04	1.05
		R^2	0.49	0.48
		r	0.70	0.69
		R.M.S.E.	0.10	0.10
3	$hf_3 = 2490.90q_3 + 148.50Q_3 - 4.41E\text{-}03p_5 + 0.1402$	D	1.00	0.99
		R^2	0.04	0.03
		r	0.20	0.18
		R.M.S.E.	0.05	0.05
4	$hf_4 = 4463.33q_4 - 811.79Q_4 - 7.16E\text{-}03p_7 + 0.1873$	D	0.98	0.97
		R^2	0.20	0.15
		r	0.45	0.38
		R.M.S.E.	0.08	0.08
5	$hf_5 = -17528.3q_5 - 4470.6Q_5 + 1.86E\text{-}02p_9 + 0.388$	D	1.03	0.97
		R^2	0.28	0.36
		r	0.53	0.60
		R.M.S.E.	0.08	0.07
6	$hf_6 = -\ 594.11q_6 - 34.479Q_6 - 1.21E\text{-}03p_{11} + 0.0598$	D	0.99	0.95
		R^2	0.04	0.03
		r	0.21	0.19
		R.M.S.E.	0.04	0.03
7	$hf_7 = 31084.0q_7 + 4743.6Q_7 - 3.32E\text{-}02p_{13} - 0.1447$	D	1.01	0.99
		R^2	0.16	0.21
		r	0.40	0.46
		R.M.S.E.	0.03	0.02
8	$hf_8 = 19932.7q_8 + 2578.9Q_8 - 1.85E\text{-}02p_{15} - 0.0580$	D	1.00	1.00
		R^2	0.05	0.06
		r	0.22	0.24
		R.M.S.E.	0.03	0.03

Table 5.8: Regression Equations for Minor Head Loss at Outlets of 12 mm Lateral for 1 Microtube

Outlet No.	Model for determining minor head losses	Summary of preparation and validation of model		
		Particular	Model	
			Preparation	Validation
1	$hf_1 = 2012.01q_1 + 972.55Q_1 - 0.0010p_1 + 0.0445$	D	1.01	0.99
		R^2	0.22	0.17
		r	0.47	0.41
		R.M.S.E.	0.04	0.04
2	$hf_2 = 1513.90q_2 + 887.25Q_2 - 0.0009p_3 + 0.0560$	D	1.00	1.00
		R^2	0.27	0.18
		r	0.52	0.42
		R.M.S.E.	0.03	0.03
3	$hf_3 = -428.73q_3 + 403.45Q_3 - 0.0002p_5 + 0.0893$	D	1.00	1.01
		R^2	0.07	0.07
		r	0.27	0.27
		R.M.S.E.	0.03	0.03
4	$hf_4 = 3443.4q_4 + 492.01Q_4 + 0.000050p_7 + 0.0826$	D	1.00	0.99
		R^2	0.04	0.07
		r	0.21	0.26
		R.M.S.E.	0.06	0.05
5	$hf_5 = 2493.20q_5 + 713.55Q_5 - 0.00246p_9 + 0.0710$	D	1.00	1.02
		R^2	0.24	0.24
		r	0.49	0.49
		R.M.S.E.	0.03	0.03
6	$hf_6 = 3455.11q_6 + 621.01Q_6 - 0.0026p_{11} + 0.0723$	D	1.00	1.00
		R^2	0.31	0.30
		r	0.55	0.55
		R.M.S.E.	0.02	0.02
7	$hf_7 = 4034.14q_7 + 640.05Q_7 - 0.0026p_{13} + 0.0720$	D	1.00	0.99
		R^2	0.30	0.30
		r	0.55	0.55
		R.M.S.E.	0.02	0.02
8	$hf_8 = 2482.17q_8 + 320.97Q_8 - 0.00213p_{15} + 0.0878$	D	1.00	1.00
		R^2	0.18	0.27
		r	0.42	0.52
		R.M.S.E.	0.01	0.01

Table 5.11: Regression Equations for Head Loss through Polytube attached to 20 mm Lateral at Various Outlets for 1 Microtube

Outlet No.	Model for determining head losses through polytube	Summary of preparation and validation of model		
		Particular	Model	
			Preparation	Validation
1	$hp_1 = -0.099lp - 0.184dp + 92125.391q - 0.166$	D	0.98	1.01
		R^2	0.34	0.31
		r	0.58	0.56
		R.M.S.E.	0.29	0.28
2	$hp_2 = 0.111lp - 8.461dp + 81287.327q - 0.164$	D	0.99	0.99
		R^2	0.47	0.45
		r	0.69	0.67
		R.M.S.E.	0.19	0.19
3	$hp_3 = 0.127lp - 21.996dp + 75113.998q - 0.059$	D	1.00	1.02
		R^2	0.49	0.46
		r	0.70	0.68
		R.M.S.E.	0.18	0.19
4	$hp_4 = 0.152lp - 30.786dp + 67216.900q + 0.026$	D	0.98	0.99
		R^2	0.48	0.44
		r	0.69	0.66
		R.M.S.E.	0.17	0.19
5	$hp_5 = 0.138lp - 22.442dp + 59202.547q + 0.030$	D	1.00	0.96
		R^2	0.47	0.45
		r	0.69	0.67
		R.M.S.E.	0.16	0.16
6	$hp_6 = 0.141lp - 8.511dp + 48761.921q - 0.012$	D	0.99	1.01
		R^2	0.56	0.58
		r	0.75	0.76
		R.M.S.E.	0.12	0.11
7	$hp_7 = 0.048lp - 12.664dp + 44511.406q + 0.037$	D	0.98	0.99
		R^2	0.53	0.53
		r	0.73	0.73
		R.M.S.E.	0.11	0.12
8	$hp_8 = -0.044lp - 12.752dp + 29314.528q + 0.124$	D	0.99	1.00
		R^2	0.36	0.34
		r	0.60	0.58
		R.M.S.E.	0.11	0.11

Table 5.15: Regression Equations for Head Loss through Polytube attached to 16 mm Lateral at Various Outlets for 1 Microtube

Outlet No.	Model for determining minor head losses	Summary of preparation and validation of model		
		Particular	Model	
			Preparation	Validation
1	hp_1 = 0.01527lp - 0.6227dp + 15100q - 0.0074	D	0.99	1.01
		R^2	0.47	0.48
		r	0.69	0.69
		R.M.S.E.	0.04	0.04
2	hp_2 = 0.0172lp + 2.5971dp + 16400q - 0.0416	D	1.00	1.01
		R^2	0.51	0.48
		r	0.71	0.70
		R.M.S.E.	0.04	0.04
3	hp_3 = 0.01602lp + 3.1006dp + 19000q - 0.0570	D	1.00	0.99
		R^2	0.56	0.55
		r	0.75	0.74
		R.M.S.E.	0.04	0.04
4	hp_4 = 0.013lp + 3.521dp + 20431.043q - 0.066	D	1.00	1.00
		R^2	0.60	0.63
		r	0.77	0.79
		R.M.S.E.	0.04	0.04
5	hp_5 = 0.010lp + 4.788dp + 21148.548q - 0.076	D	1.01	1.06
		R^2	0.61	0.60
		r	0.78	0.77
		R.M.S.E.	0.04	0.04
6	hp_6 = 0.016lp + 9.990dp + 22599.14q - 0.105	D	1.00	1.00
		R^2	0.63	0.64
		r	0.79	0.80
		R.M.S.E.	0.04	0.04
7	hp_7 = 0.016lp + 10.501dp + 23679.77q - 0.112	D	0.99	0.97
		R^2	0.62	0.62
		r	0.79	0.79
		R.M.S.E.	0.04	0.04
8	hp_8 = 0.015lp + 11.471dp + 21131.22q - 0.100	D	0.99	1.00
		R^2	0.57	0.56
		r	0.75	0.75
		R.M.S.E.	0.04	0.04

Table 5.18: Regression Equations for Head Loss through Polytube attached to 12 mm Lateral at Various Outlets for 1 Microtube

Outlet No.	Model for determining minor head losses	Summary of preparation and validation of model		
		Particular	Model	
			Preparation	Validation
1	$hp_1 = 0.90lp - 570.83dp + 380454.54q + 2.64$	D	1.01	0.99
		R^2	0.36	0.35
		r	0.60	0.59
		R.M.S.E.	1.15	1.18
2	$hp_2 = 1.4691lp - 187.41dp + 393176.48 + 0.4055$	D	0.99	0.98
		R^2	0.33	0.34
		r	0.57	0.59
		R.M.S.E.	1.05	1.04
3	$hp_3 = 0.963lp + 266.11dp + 352271.24q - 1.896$	D	0.98	0.95
		R^2	0.39	0.41
		r	0.62	0.64
		R.M.S.E.	0.95	0.94
4	$hp_4 = 0.944lp + 267.643dp + 328155.42q - 1.897$	D	0.98	0.99
		R^2	0.40	0.41
		r	0.63	0.64
		R.M.S.E.	0.85	0.83
5	$hp_5 = 1.312lp - 241.94dp + 361201.15q + 0.612$	D	0.99	0.97
		R^2	0.24	0.21
		r	0.49	0.46
		R.M.S.E.	1.14	1.16
6	$hp_6 = 1.737lp + 57.46dp + 342744.58q - 1.421$	D	0.96	1.00
		R^2	0.39	0.38
		r	0.62	0.62
		R.M.S.E.	0.78	0.79
7	$hp_7 = 1.629lp + 11.59dp + 393498.46q - 1.570$	D	1.05	0.87
		R^2	0.26	0.28
		r	0.51	0.53
		R.M.S.E.	1.16	1.07
8	$hp_8 = 0.541lp - 45.804dp + 144621.608q - 0.029$	D	1.02	1.02
		R^2	0.19	0.16
		r	0.44	0.40
		R.M.S.E.	0.50	0.56

F factor for ITK MIS

F factor is determined for 20 mm lateral for various diameters and lengths of polytubes.

Table 5.21 gives F factor for 20 mm lateral – 4 mm dia and 0.15 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures.

Table 5.22 illustrates F factor for 20 mm lateral – 4 mm dia and 0.30 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD.

Table 5.23 shows F factor for 20 mm lateral – 4 mm dia and 0.45 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD.

Table 5.24 gives F factor for 20 mm lateral – 4 mm dia and 0.60 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD..

Table 5.25 illustrates F factor for 20 mm lateral – 4 mm dia and 0.75 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD.

Table 5.26 shows F factor for 20 mm lateral – 4 mm dia and 0.90 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD..

Table 5.21: F factor for 20 mm Lateral – 4 mm dia and 0.15 m long Polytube

No.of Outlets	F factor					
	2 microtubes		3 microtubes		4 microtubes	
	12	7.5	15	8	15.5	10
	mwc	mwc	mwc	mwc	mwc	mwc
1	1.000	1.022	1.000	1.000	1.000	1.000
2	0.657	0.532	0.623	0.550	0.794	0.707
3	0.487	0.401	0.472	0.421	0.662	0.597
4	0.394	0.328	0.388	0.348	0.581	0.530
5	0.334	0.281	0.333	0.300	0.526	0.483
6	0.292	0.248	0.294	0.266	0.484	0.448
7	0.260	0.222	0.265	0.240	0.452	0.420
8	0.236	0.203	0.242	0.220	0.426	0.398
9	0.216	0.187	0.223	0.203	0.404	0.379
10	0.200	0.173	0.208	0.190	0.385	0.362
11	0.186	0.162	0.195	0.178	0.369	0.348
12	0.175	0.153	0.183	0.168	0.355	0.336
13	0.164	0.144	0.174	0.159	0.342	0.325
14	0.156	0.137	0.165	0.152	0.331	0.315
15	0.148	0.131	0.158	0.145	0.321	0.306
16	0.141	0.125	0.151	0.139	0.311	0.298
17	0.135	0.120	0.145	0.133	0.303	0.291
18	0.129	0.115	0.139	0.128	0.295	0.284
19	0.124	0.111	0.134	0.124		0.278
20	0.120	0.107	0.129	0.120		0.272
21	0.115	0.103		0.116		0.266
22	0.111	0.100		0.113		0.261
23	0.108	0.097		0.109		0.257
24	0.105	0.094		0.106		0.252
25	0.101	0.092		0.103		0.248
26	0.098	0.089		0.101		0.244
27	0.096	0.087		0.098		0.240
28	0.093	0.085		0.096		0.236
29	0.091	0.083		0.094		0.233
30	0.089	0.081		0.092		0.230
31	0.086	0.079		0.090		0.227
32	0.084	0.077		0.088		0.224
33	0.083	0.076		0.086		0.221
34	0.081	0.074		0.084		0.218
35	0.079	0.072		0.083		0.216
36	0.077	0.071		0.081		0.213
37	0.076	0.070		0.080		0.211
38	0.074	0.068		0.078		0.208
39	0.073	0.067		0.077		0.206
40	0.072	0.066		0.076		0.204
41	0.070	0.065		0.075		0.202
42	0.069	0.064		0.073		0.200
43	0.068	0.063		0.072		0.198
44	0.067	0.062		0.071		0.196
45	0.066	0.061		0.070		0.194

No.of Outlets	F factor					
	2 microtubes		3 microtubes		4 microtubes	
	12	7.5	15	8	15.5	10
46	0.065	0.060		0.069		0.192
47	0.064	0.059		0.068		0.191
48	0.063	0.058		0.067		
49	0.062	0.057		0.066		
50		0.057		0.065		
51		0.056		0.064		
52		0.055		0.064		
53		0.054		0.063		
54		0.054		0.062		
55		0.053		0.061		
56		0.052		0.061		
57		0.052		0.060		
58		0.051		0.059		
59		0.050		0.059		
60		0.050		0.058		
61		0.049		0.057		
62		0.049		0.057		
63		0.048		0.056		
64		0.048		0.055		
65		0.047		0.055		
66		0.047		0.054		
67		0.046		0.054		
68		0.046		0.053		
69		0.045		0.053		
70		0.045		0.052		
71		0.044		0.052		
72		0.044		0.051		
73		0.043		0.051		
74		0.043		0.050		
75		0.043		0.050		
76		0.042		0.050		
77		0.042		0.049		
78		0.041		0.049		
79		0.041		0.048		
80		0.041		0.048		
81		0.040		0.047		
82		0.040		0.047		
83		0.040		0.047		
84		0.039		0.046		
85		0.039		0.046		
86		0.039		0.046		
87		0.038		0.045		
88		0.038				
89		0.038				
90		0.038				
91		0.037				
92		0.037				

Table 5.27 gives F factor for 20 mm lateral – 5 mm dia and 0.15 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures.

Table 5.28 illustrate F factor for 20 mm lateral – 5 mm dia and 0.30 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD.

Table 5.29 shows F factor for 20 mm lateral – 5 mm dia and 0.45 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD.

Table 5.30 gives F factor for 20 mm lateral – 5 mm dia and 0.60 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD.

Table 5.31 illustrate F factor for 20 mm lateral – 5 mm dia and 0.75 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD.

Table 5.32 shows F factor for 20 mm lateral – 5 mm dia and 0.90 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD.

Table 5.33 gives F factor for 20 mm lateral – 6 mm dia and 0.15 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures.

Table 5.34 illustrate F factor for 20 mm lateral – 6 mm dia and 0.30 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD.

Table 5.27: F Factor for 20 mm Lateral – 5 mm Dia and 0.15 m Long Polytube

No.of Outlets	F factor					
	2 microtubes		3 microtubes		4 microtubes	
	15 mwc	10 mwc	13.5 mwc	5.5 mwc	15.5 mwc	10.5 mwc
1	1.000	1.010	1.001	1.001	1.010	1.000
2	0.633	0.774	0.657	0.657	0.623	0.805
3	0.501	0.657	0.549	0.533	0.515	0.684
4	0.424	0.584	0.484	0.459	0.451	0.609
5	0.373	0.534	0.438	0.409	0.406	0.557
6	0.336	0.496	0.404	0.373	0.373	0.518
7	0.307	0.466	0.378	0.344	0.347	0.487
8	0.285	0.442	0.356	0.317	0.326	0.461
9	0.266	0.421	0.338	0.308	0.309	0.440
10	0.250	0.403	0.323	0.293	0.294	0.422
11	0.237	0.388	0.309	0.280	0.281	0.406
12	0.225	0.375	0.298	0.269	0.270	0.392
13	0.215	0.363	0.287	0.259	0.260	0.379
14	0.206	0.352	0.278	0.250	0.251	0.368
15	0.198	0.342	0.270	0.242	0.243	0.358
16	0.191	0.334	0.262	0.234		0.349
17	0.184	0.325	0.255	0.228		0.341
18	0.178	0.318	0.249	0.221		0.333
19	0.173	0.311	0.243	0.216		0.326
20	0.168	0.305	0.237	0.211		0.319
21	0.163	0.299	0.232	0.206		0.313
22	0.159	0.293	0.228	0.201		0.307
23	0.155	0.288	0.223	0.197		0.302
24	0.151	0.283	0.219	0.193		0.297
25		0.278	0.215	0.189		0.292
26		0.274	0.211	0.186		0.287
27		0.270	0.208	0.183		0.283
28		0.266	0.205	0.180		0.279
29		0.262	0.201	0.177		0.275
30		0.259	0.198	0.174		0.271
31		0.255	0.196	0.171		0.268
32		0.252	0.193	0.168		0.264
33		0.249	0.190	0.166		0.261
34		0.246	0.188	0.164		0.258
35		0.243		0.161		0.255
36		0.240		0.159		0.252
37		0.238		0.157		
38		0.235		0.155		
39				0.153		
40				0.152		
41				0.150		
42				0.148		
43				0.146		
44				0.145		
45				0.143		

No.of Outlets	F factor					
	2 microtubes		3 microtubes		4 microtubes	
	15	**10**	**13.5**	**5.5**	**15.5**	**10.5**
	mwc	mwc	mwc	mwc	mwc	mwc
46				0.142		
47				0.140		
48				0.139		
49				0.138		
50				0.136		
51				0.135		
52				0.134		
53				0.133		
54				0.131		
55				0.130		
56				0.129		
57				0.128		
58				0.126		
59				0.125		
60				0.124		
61				0.123		
62				0.123		
63				0.122		
64				0.121		
65				0.120		
66				0.119		
67				0.118		
68				0.117		
69				0.116		

Table 5.33: F Factor for 20 mm Lateral – 6 mm dia and 0.15 m long Polytube

No.of Outlets	F factor					
	2 microtubes		3 microtubes		4 microtubes	
	15.50	14.00	12.00	5.00	13.00	9.75
	mwc	mwc	mwc	mwc	mwc	mwc
1	0.990	0.980	1.002	1.020	1.002	1.004
2	0.743	0.723	0.821	0.631	0.887	0.652
3	0.642	0.614	0.728	0.512	0.736	0.507
4	0.580	0.548	0.622	0.441	0.644	0.423
5	0.535	0.501	0.551	0.393	0.581	0.369
6	0.502	0.465	0.499	0.358	0.534	0.329
7	0.475	0.437	0.459	0.331	0.498	0.299
8	0.453	0.415	0.427	0.309	0.468	0.275
9	0.434	0.396	0.401	0.291	0.443	0.256
10	0.418	0.379	0.378	0.275	0.422	0.239
11	0.404	0.365	0.359	0.262	0.404	0.225
12	0.392	0.352	0.343	0.250	0.388	0.214
13	0.381	0.341	0.328	0.240	0.374	0.203
14	0.371	0.331	0.315	0.231	0.362	0.194
15	0.362	0.322	0.304	0.223	0.350	0.186
16	0.353	0.314	0.293	0.216	0.340	0.179
17	0.346	0.306	0.284	0.209	0.331	0.172
18	0.339	0.300	0.275	0.203	0.322	0.166
19	0.332	0.293	0.267	0.198	0.314	0.160
20	0.326	0.287	0.260	0.192	0.307	0.155
21	0.321	0.282	0.253	0.188		0.151
22	0.315	0.276	0.247	0.183		0.146
23	0.310	0.271	0.241	0.179		0.142
24	0.306	0.267	0.235	0.175		0.139
25		0.263	0.230	0.171		0.135
26		0.258	0.225	0.168		0.132
27		0.255	0.221	0.165		0.129
28		0.251		0.162		0.126
29		0.247		0.159		0.123
30		0.244		0.156		0.121
31		0.241		0.153		0.118
32		0.238		0.151		0.116
33		0.235		0.149		0.114
34		0.232		0.146		0.112
35		0.229		0.144		0.110
36		0.227		0.142		0.108
37		0.224		0.140		0.106
38		0.222		0.138		0.104
39		0.220		0.136		0.102
40		0.217		0.135		0.101
41		0.215		0.133		0.099
42		0.213		0.131		0.098
43		0.211		0.130		0.096
44		0.209		0.128		0.095

No.of Outlets	F factor					
	2 microtubes		3 microtubes		4 microtubes	
	15.50	**14.00**	**12.00**	**5.00**	**13.00**	**9.75**
	mwc	mwc	mwc	mwc	mwc	mwc
45		0.207		0.127		0.094
46		0.206		0.125		0.092
47		0.204		0.124		0.091
48		0.202		0.122		0.090
49		0.200		0.121		0.089
50		0.199		0.120		0.088
51		0.197		0.119		0.087
52		0.196		0.118		0.086
53		0.194		0.116		0.085
54		0.193		0.115		0.084
55		0.191		0.114		0.083
56		0.190		0.113		0.082
57		0.189		0.112		0.081
58		0.187		0.111		
59		0.186		0.110		
60		0.185				
61		0.184				
62		0.182				
63		0.181				
64		0.180				
65		0.179				
66		0.178				
67		0.177				
68		0.176				
69		0.175				
70		0.174				
71		0.173				
72		0.172				
73		0.171				
74		0.170				
75		0.169				
76		0.168				
77		0.167				
78		0.166				
79		0.166				

Table 5.35 shows F factor for 20 mm lateral – 6 mm dia and 0.45 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD.

Table 5.36 gives F factor for 20 mm lateral – 6 mm dia and 0.60 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD.

Table 5.37 illustrate F factor for 20 mm lateral – 6 mm dia and 0.75 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD.

Table 5.38 shows F factor for 20 mm lateral – 6 mm dia and 0.90 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD.

Table 5.39 gives F factor for 20 mm lateral – 7 mm dia and 0.15 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures.

Table 5.40 illustrate F factor for 20 mm lateral – 7 mm dia and 0.30 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD.

Table 5.41 shows F factor for 20 mm lateral – 7 mm dia and 0.45 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD.

Table 5.42 gives F factor for 20 mm lateral – 7 mm dia and 0.60 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD.

Table 5.39: F factor for 20 mm Lateral – 7 mm dia and 0.15 m long Polytube

No.of Outlets	F factor					
	2 microtubes		3 microtubes		4 microtubes	
	15	6	10	5	15	10
	mwc	mwc	mwc	mwc	mwc	mwc
1	1.011	0.980	0.991	1.020	1.002	1.010
2	0.816	0.651	0.626	0.728	0.869	0.689
3	0.683	0.517	0.501	0.581	0.710	0.543
4	0.601	0.440	0.427	0.496	0.616	0.459
5	0.545	0.388	0.378	0.438	0.551	0.403
6	0.503	0.350	0.341	0.396	0.504	0.362
7	0.470	0.321	0.314	0.364	0.467	0.331
8	0.443	0.297	0.291	0.338	0.437	0.306
9	0.421	0.278	0.273	0.316	0.412	0.286
10	0.402	0.262	0.258	0.298	0.391	0.269
11	0.385	0.248	0.244	0.283	0.373	0.254
12	0.371	0.236	0.233	0.270	0.357	0.241
13	0.358	0.226	0.223	0.258	0.343	0.230
14	0.347	0.217	0.214	0.248	0.331	0.221
15	0.336	0.208	0.206	0.238	0.320	0.212
16	0.327	0.201	0.199	0.230	0.310	0.204
17	0.318	0.194	0.192	0.222	0.301	0.197
18	0.310	0.188	0.186	0.215	0.292	0.190
19	0.303	0.182	0.181	0.209	0.284	0.184
20	0.296	0.177	0.176	0.203	0.277	0.179
21	0.290	0.172	0.171	0.198	0.271	0.174
22	0.284	0.168	0.167	0.193	0.264	0.169
23	0.279	0.164	0.163	0.188	0.259	0.165
24	0.273	0.160	0.159	0.184	0.253	0.161
25		0.156	0.155	0.180		0.157
26		0.153	0.152	0.176		0.154
27		0.150	0.149	0.172		0.150
28		0.146	0.146	0.169		0.147
29		0.144	0.143	0.165		0.144
30		0.141	0.140	0.162		0.141
31		0.138	0.138	0.159		0.139
32		0.136	0.136	0.157		0.136
33		0.134	0.133	0.154		0.134
34		0.131	0.131	0.151		0.131
35		0.129	0.129	0.149		0.129
36		0.127	0.127	0.147		0.127
37		0.125	0.125	0.145		0.125
38		0.123	0.123	0.142		0.123
39		0.121	0.122			
40		0.120	0.120			
41		0.118	0.118			
42		0.116	0.117			
43		0.115	0.115			
44		0.113	0.114			

No.of Outlets	F factor					
	2 microtubes		3 microtubes		4 microtubes	
	15	6	10	5	15	10
	mwc	mwc	mwc	mwc	mwc	mwc
45			0.112			
46			0.111			
47			0.110			
48			0.108			
49			0.107			
50			0.106			
51			0.105			
52			0.104			

Table 5.43 illustrates F factor for 20 mm lateral – 7 mm dia and 0.75 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD.

Table 5.44 shows F factor for 20 mm lateral – 7 mm dia and 0.90 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD.

Development of the relationship between inlet pressure and microtube discharge and length of microtubes and inlet pressure.

The relationship between inlet pressures and discharge through microtubes are established.

Table 5.45 gives inlet pressure vs microtube discharges of various diameter and lengths of microtube for 20 mm lateral – 4 mm dia and 0.15 m long polytube – 2 microtubes.

Table 5.46 indicates inlet pressure- microtube discharge regression equations for various diameter and length of microtubes for 20 mm lateral – 4 mm dia and 0.15 m long polytube – 2 microtubes.

Table 5.47 gives microtube length - inlet pressure regression equations for various diameter of microtubes for 20 mm lateral – 4 mm dia and 0.15 m long polytube – 2 microtubes

Table 5.45: Inlet Pressure Vs Microtube Discharges of Various Diameter and Length of Microtubes
20 mm dia Lateral -4 mm dia and 0.15 m long Polytube – 2 Microtubes

	Avg. Discharges of One Microtube, lph								
P2	1.5-0.30	1.5-0.60	1.5-0.90	1.2-0.30	1.2-0.60	1.2-0.90	1.0-0.30	1.0-0.60	1.0-0.90
Mwc	lph	lph	lph	lph	lph	lph	lph	lph	lph
15.50	23.52	19.58	16.46	21.12	18.03	14.78	19.92	16.93	13.94
14.83	23.13	19.25	16.19	20.73	17.70	14.51	19.53	16.60	13.67
14.15	22.54	18.75	15.78	20.14	17.19	14.10	18.94	16.10	13.26
13.48	22.15	18.42	15.51	19.75	16.86	13.83	18.55	15.77	12.99
12.80	21.71	18.04	15.19	19.31	16.48	13.51	18.11	15.39	12.67
12.60	21.47	17.84	15.03	19.07	16.27	13.35	17.87	15.19	12.51
12.40	21.32	17.71	14.92	18.92	16.15	13.24	17.72	15.06	12.40
12.20	21.08	17.51	14.76	18.68	15.94	13.08	17.48	14.86	12.24
12.00	20.69	17.18	14.48	18.29	15.61	12.80	17.09	14.53	11.96
11.73	20.39	16.93	14.28	17.99	15.35	12.60	16.79	14.28	11.76
11.45	20.25	16.80	14.17	17.85	15.23	12.49	16.65	14.15	11.65
11.18	20.10	16.68	14.07	17.70	15.10	12.39	16.50	14.02	11.55
10.90	19.86	16.47	13.90	17.46	14.89	12.22	16.26	13.82	11.38
10.45	18.73	15.51	13.11	16.33	13.93	11.43	15.13	12.86	10.59
10.00	17.45	14.43	12.22	15.05	12.84	10.54	13.85	11.77	9.70
9.60	17.12	14.14	11.98	14.72	12.55	10.30	13.52	11.49	9.46
9.20	16.97	14.02	11.88	14.57	12.42	10.20	13.37	11.37	9.36
8.78	16.82	13.89	11.78	14.42	12.30	10.10	13.22	11.24	9.26
8.35	16.68	13.77	11.67	14.28	12.17	9.99	13.08	11.11	9.15
7.93	16.53	13.64	11.57	14.13	12.04	9.89	12.93	10.99	9.05
7.50	16.44	13.56	11.51	14.04	11.96	9.83	12.84	10.91	8.99
7.00	16.20	14.14	12.96	13.80	12.43	11.04	12.60	11.34	10.08
6.50	15.96	13.93	12.77	13.56	12.22	10.85	12.36	11.12	9.89
6.00	15.62	13.63	12.50	13.22	11.91	10.58	12.02	10.82	9.62
5.50	14.87	12.95	11.90	12.47	11.22	9.98	11.27	10.14	9.02
5.00	14.11	12.27	11.29	11.71	10.52	9.37	10.51	9.46	8.41
4.50	13.69	11.89	10.95	11.29	10.13	9.03	10.09	9.08	8.07
4.00	12.81	11.09	10.25	10.41	9.31	8.33	9.21	8.29	7.37
3.50	11.74	10.13	9.39	9.34	8.32	7.47	8.14	7.33	6.51
2.25	10.54	9.05	8.43	8.14	7.23	6.51	6.94	6.25	5.55
1.00	11.04	8.30	8.83	8.64	7.67	6.91	7.44	6.70	5.95
6.80	17.92	15.69	14.33	15.52	13.99	12.41	14.32	12.89	11.45
5.00	15.06	13.56	12.95	12.66	11.76	10.89	11.46	10.66	9.85
4.00	12.66	11.33	10.89	10.26	9.50	8.82	9.06	8.42	7.79

N.B. 1.5 - 0.30: 1.5 mm diameter and 0.30 m long microtube
1.2 - 0.60: 1.2 mm diameter and 0.60 m long microtube

Table 5.46: Inlet Pressure- Microtube Discharge Regression Equations for Various Diameter and Lengths of Microtube 20 mm dia Lateral -4 mm dia and 0.15 m long Polytube – 2 Microtube

Diameter of microtube	Length of microtube	Inlet Pressure-discharge equations	R^2	Estimated pressure for various discharges, mwc	
Mm	m			15 lph	10 lph
1.5	0.3	$P2= 0.0052q^{2.5684}$	0.892	5.45	1.92
1.5	0.6	$P2= 0.0059q^{2.6836}$	0.915	8.45	2.85
1.5	0.9	$P2 = 0.0028q^{3.1192}$	0.786	13.05	3.68
1.2	0.3	$P2= 0.0215q^{2.1867}$	0.898	8.02	3.30
1.2	0.6	$P2 = 0.0197q^{2.3391}$	0.883	11.10	4.30
1.2	0.9	$P2= 0.0153q^{2.6044}$	0.822	17.69	6.15
1.0	0.3	$P2= 0.0432q^{1.9925}$	0.902	9.52	4.25
1.0	0.6	$P2= 0.0385q^{2.1517}$	0.886	13.06	5.46
1.0	0.9	$P2= 0.0351q^{2.3441}$	0.838	20.05	7.75

Table 5.47: Microtube Length - Inlet Pressure Regression Equations for Various Diameter of Microtube 20 mm dia Lateral - 4mm dia and 0.15 m long Polytube - 2 Microtubes

Diameter of microtube	Microtube Length vs Inlet Pressure			
Mm	15 lph		10 lph	
	L	R^2	L	R^2
1.5	$L_{1.5} = 0.0733P2 - 0.0888$	0.9587	$L_{1.5} = 0.2906P2 - 0.2943$	0.9613
1.2	$L_{1.2} = 0.0598P2 - 0.1758$	0.9643	$L_{1.2} = 0.1861P2 - 0.3593$	0.9677
1.0	$L_{1.0} = 0.0568P2 - 0.2396$	0.9685	$L_{1.0} = 0.1564P2 - 0.4119$	0.9718

Tables 5.48 to 5.95 give inlet pressure vs microtube discharges of various diameter and length of microtubes, regression equations for inlet pressure-microtube discharge for various diameter and length of microtube, and regression equations for microtube length - inlet pressure for various diameter of microtubes for 20 mm lateral - 4 mm polytube and 0.30 m, 0.45 m, 0.60 m, 0.75 m, & 0.90 m length of polytubes considering 2,3 and 4 microtubes respectively and are given in enclosed DVD.

Table 5.96 gives inlet pressure vs microtube discharges of various diameter and lengths of microtube for 20 mm lateral – 5 mm dia and 0.15 m long polytube – 2 microtubes.

Table 5.97 indicates inlet pressure- microtube discharge regression equations for various diameter and length of microtubes for 20 mm lateral – 5 mm dia and 0.15 m long polytube – 2 microtubes.

Table 5.98 gives microtube length - inlet pressure regression equations for various diameter of microtubes for 20 mm lateral – 5 mm dia and 0.15 m long polytube – 2 microtubes

Tables 5.99 to 5.143 present inlet pressure vs microtube discharges of various diameter and length of microtubes, regression equations for inlet pressure- microtube discharge for various diameter and length of microtubes, and regression equations for microtube length - inlet pressure for various diameter of microtubes for 20 mm lateral - 5 mm polytube and 0.30 m, 0.45 m, 0,60 m, 0.75 m, & 0.90 m length of polytubes considering 2,3 and 4 microtubes respectively and are given in enclosed DVD.

Table 5.96: Inlet Pressure Vs Microtube Discharges of Various Diameter and Length of Microtubes
20 mm Lateral - 5 mm dia and 0.15 m Long Polytube - 2-Microtubes

	Avg. Discharges of One Microtube, lph								
P2	1.5-30	1.5-60	1.5-90	1.2-30	1.2-60	1.2-90	1.0-30	1.0-60	1.0-90
mwc	lph	lph	lph	lph	lph	lph	lph	lph	lph
15.00	21.50	18.27	15.05	19.10	16.23	13.37	17.90	15.21	12.53
14.75	21.41	18.19	14.98	19.01	16.15	13.30	17.81	15.13	12.46
14.50	21.26	18.07	14.88	18.86	16.03	13.20	17.66	15.01	12.36
14.25	21.02	17.86	14.71	18.62	15.82	13.03	17.42	14.80	12.19
14.00	20.87	17.74	14.61	18.47	15.70	12.93	17.27	14.68	12.09
13.75	20.63	17.53	14.44	18.23	15.49	12.76	17.03	14.47	11.92
13.50	20.48	17.41	14.34	18.08	15.37	12.66	16.88	14.35	11.82
13.25	20.24	17.20	14.17	17.84	15.16	12.49	16.64	14.14	11.65
13.00	20.00	17.00	14.00	17.60	14.96	12.32	16.40	13.94	11.48
12.75	19.85	16.87	13.90	17.45	14.83	12.22	16.25	13.81	11.38
12.50	19.70	16.75	13.79	17.30	14.71	12.11	16.10	13.69	11.27
12.00	19.56	16.62	13.69	17.16	14.58	12.01	15.96	13.56	11.17
11.50	19.17	16.29	13.42	16.77	14.25	11.74	15.57	13.23	10.90
11.00	18.63	15.84	13.04	16.23	13.80	11.36	15.03	12.78	10.52
10.50	18.24	15.51	12.77	15.84	13.47	11.09	14.64	12.45	10.25
10.00	17.62	14.97	12.33	15.22	12.93	10.65	14.02	11.91	9.81
9.50	17.47	14.85	12.23	15.07	12.81	10.55	13.87	11.79	9.71
9.00	17.32	14.72	12.12	14.92	12.68	10.44	13.72	11.66	9.60
8.50	17.17	14.60	12.02	14.77	12.56	10.34	13.57	11.54	9.50
8.00	16.88	14.34	11.81	14.48	12.30	10.13	13.28	11.28	9.29
7.50	16.49	14.01	11.54	14.09	11.97	9.86	12.89	10.95	9.02
7.00	16.10	14.49	12.88	13.70	12.33	10.96	12.50	11.25	10.00
6.50	15.71	14.14	12.57	13.31	11.98	10.65	12.11	10.90	9.69
6.00	14.93	13.44	11.95	12.53	11.28	10.03	11.33	10.20	9.07
5.50	14.18	12.76	11.34	11.78	10.60	9.42	10.58	9.52	8.46
5.00	13.42	12.08	10.74	11.02	9.92	8.82	9.82	8.84	7.86
4.50	12.82	11.53	10.25	10.42	9.37	8.33	9.22	8.29	7.37
4.00	12.21	10.99	9.77	9.81	8.83	7.85	8.61	7.75	6.89
3.50	11.45	10.31	9.16	9.05	8.15	7.24	7.85	7.07	6.28
3.00	10.24	9.21	8.19	7.84	7.05	6.27	6.64	5.97	5.31
2.50	9.31	8.38	7.45	6.91	6.22	5.53	5.71	5.14	4.57
2.00	8.39	7.55	6.71	5.99	5.39	4.79	4.79	4.31	3.83
1.50	7.46	6.94	6.42	5.06	4.71	4.36	3.86	3.59	3.32
1.00	6.36	5.91	5.47	3.96	3.68	3.40	2.76	2.56	2.37

Table 5.97: Inlet Pressure- Microtube Discharge Regression Equations for Various Diameter and Length of Microtubes 20 mm Lateral - 5 mm dia and 0.15 m Long Polytube - 2-Microtubes

Diameter of microtube	Length of microtube	Pressure-discharge equation	R^2	Estimated pressure for various discharges, mwc	
mm	m			20	10
1.5	0.3	$P2 = 0.017q^{2.198}$	0.994	9.31	4.65
1.5	0.6	$P2 = 0.014q^{2.393}$	0.987	10.68	5.34
1.5	0.9	$P2 = 0.010q^{2.679}$	0.966	12.56	6.28
1.2	0.3	$P2 = 0.080q^{1.751}$	0.989	11.12	5.56
1.2	0.6	$P2 = 0.076q^{1.871}$	0.983	12.78	6.39
1.2	0.9	$P2 = 0.070q^{2.041}$	0.966	15.06	7.53
1.0	0.3	$P2 = 0.176q^{1.509}$	0.983	12.40	6.20
1.0	0.6	$P2 = 0.178q^{1.596}$	0.976	14.26	7.13
1.0	0.9	$P2 = 0.177q^{1.717}$	0.960	16.78	8.39

Table 5.98: Microtube Length - Inlet Pressure Regression Equations for Various Diameter of Microtubes 20 mm Lateral - 5 mm dia and 0.15 m long Polytube - 2 Microtubes

Diameter of microtube	Pressure -Length Equations			
mm	20 lph		10 lph	
	L	R^2	L	R^2
1.5	$L_{1.5} = 0.183P2 - 1.385$	0.991	$L_{1.5} = 0.365P2 - 1.381$	0.992
1.2	$L_{1.2} = 0.151P2 - 1.361$	0.991	$L_{1.2} = 0.302P2 - 1.361$	0.991
1.0	$L_{1.0} = 0.136P2 - 1.368$	0.992	$L_{1.0} = 0.271P2 - 1.368$	0.992

Table 5.144 gives inlet pressure vs microtube discharges of various diameter and lengths of microtube for 20 mm lateral – 6 mm dia and 0.15 m long polytube – 2 microtubes.

Table 5.145 indicates inlet pressure- microtube discharge regression equations for various diameter and length of microtubes for 20 mm lateral – 6 mm dia and 0.15 m long polytube – 2 microtubes.

Table 5.146 gives microtube length - inlet pressure regression equations for various diameter of microtubes for 20 mm lateral – 6 mm dia and 0.15 m long polytube – 2 microtubes

Tables 5.147 to 5.197 present inlet pressure vs microtube discharges of various diameter and length of microtubes, regression equations for inlet pressure- microtube discharge for various diameter and length of microtubes, and regression equations for microtube length - inlet pressure for various diameter of microtubes for 20 mm lateral - 6 mm polytube and 0.30 m, 0.45 m, 0,60 m, 0.75 m, & 0.90 m length of polytubes considering 2,3 and 4 microtubes respectively and are given in enclosed DVD

Table 5.198 gives inlet pressure vs microtube discharges of various diameter and lengths of microtube for 20 mm lateral – 7 mm dia and 0.15 m long polytube – 2 microtubes.

Table 5.199 indicates inlet pressure- microtube discharge regression equations for various diameter and length of microtubes for 20 mm lateral – 7 mm dia and 0.15 m long polytube – 2 microtubes.

Table 5.200 gives microtube length - inlet pressure regression equations for various diameter of microtubes for 20 mm lateral – 7 mm dia and 0.15 m long polytube – 2 microtubes

Table 5.144: Inlet Pressure Vs Microtube Discharges of Various Diameter and Length of Microtubes
20 mm Lateral - 6 mm dia and 0.15 m Long Polytube - 2-Microtubes

	Avg. Discharges of One Microtube, lph								
P2	**1.5-30**	**1.5-60**	**1.5-90**	**1.2-30**	**1.2-60**	**1.2-90**	**1.0-30**	**1.0-60**	**1.0-90**
mwc	**lph**	**lph**	**lph**	**lph**	**lph**	**lph**	**lph**	**lph**	**lph**
15.50	46.32	39.37	32.42	43.92	37.33	30.74	42.72	36.31	29.90
15.00	47.37	40.26	33.16	44.97	38.22	31.48	43.77	37.20	30.64
14.50	42.69	36.29	29.88	40.29	34.25	28.20	39.09	33.23	27.36
14.00	40.62	34.53	28.43	38.22	32.49	26.75	37.02	31.47	25.91
13.50	39.12	33.25	27.38	36.72	31.21	25.70	35.52	30.19	24.86
13.00	37.59	31.95	26.31	35.19	29.91	24.63	33.99	28.89	23.79
12.50	36.42	30.96	25.49	34.02	28.92	23.81	32.82	27.90	22.97
12.00	35.40	30.09	24.78	33.00	28.05	23.10	31.80	27.03	22.26
11.50	34.65	29.45	24.26	32.25	27.41	22.58	31.05	26.39	21.74
11.00	33.84	28.76	23.69	31.44	26.72	22.01	30.24	25.70	21.17
10.50	33.27	28.28	23.29	30.87	26.24	21.61	29.67	25.22	20.77
10.00	32.70	27.80	22.89	30.30	25.76	21.21	29.10	24.74	20.37
9.50	30.03	25.53	21.02	27.63	23.49	19.34	26.43	22.47	18.50
9.00	27.33	23.23	19.13	24.93	21.19	17.45	23.73	20.17	16.61
8.50	25.20	21.42	17.64	22.80	19.38	15.96	21.60	18.36	15.12
8.00	22.95	19.51	16.07	20.55	17.47	14.39	19.35	16.45	13.55
7.50	22.08	18.77	15.46	19.68	16.73	13.78	18.48	15.71	12.94
7.00	21.21	18.03	14.85	18.81	15.99	13.17	17.61	14.97	12.33
6.50	20.70	17.60	14.49	18.30	15.56	12.81	17.10	14.54	11.97
6.00	20.16	17.14	14.11	17.76	15.10	12.43	16.56	14.08	11.59
5.50	19.32	16.42	13.52	16.92	14.38	11.84	15.72	13.36	11.00
5.00	18.63	16.01	13.39	16.23	13.95	11.68	15.03	12.93	10.82
4.50	17.73	15.24	12.74	15.33	13.18	11.03	14.13	12.15	10.18
4.00	16.86	14.49	12.12	14.46	12.43	10.41	13.26	11.41	9.55
3.50	15.66	13.46	11.26	13.26	11.41	9.55	12.06	10.38	8.70
3.00	14.52	12.48	10.45	12.12	10.43	8.74	10.92	9.40	7.88

Table 5.145: Inlet Pressure- Microtube Discharge Regression Equations for Various Diameter and Length of Microtubes
20 mm Lateral - 6 mm dia and 0.15 m Long Polytube - 2-Microtubes

Diameter of microtube	Length of microtube	Pressure-discharge equation	R^2	Estimated pressure for various discharges, mwc	
mm	m			20	10
1.5	0.3	$P2 = 0.1129q^{1.3034}$	0.960	5.60	2.27
1.5	0.6	$P2 = 0.1352q^{1.3126}$	0.957	6.90	2.78
1.5	0.9	$P2 = 0.1673q^{1.3253}$	0.952	8.87	3.54
1.2	0.3	$P2 = 0.1885q^{1.1837}$	0.965	6.54	2.88
1.2	0.6	$P2 = 0.2222q^{1.1919}$	0.962	7.90	3.46
1.2	0.9	$P2 = 0.27q^{1.2034}$	0.958	9.93	4.31
1.0	0.3	$P2 = 0.2435q^{1.1228}$	0.968	7.04	3.23
1.0	0.6	$P2 = 0.2847q^{1.1306}$	0.965	8.42	3.85
1.0	0.9	$P2 = 0.3427q^{1.1415}$	0.961	10.47	4.75

Table 5.146: Microtube Length - Inlet Pressure Regression Equations for Various Diameter of Microtubes
20 mm Lateral - 6 mm dia and 0.15 m long Polytube - 2 Microtubes

Diameter of microtube	Pressure -Length Equations			
mm	20 lph		10 lph	
	L	R^2	L	R^2
1.5	$L_{1.5}$= 0.1813P2 - 0.6913	0.986	$L_{1.5}$= 0.4669P2 - 0.7363	0.986
1.2	$L_{1.2}$ = 0.1744P2 - 0.8166	0.987	$L_{1.2}$= 0.302P2 - 1.361	0.991
1.0	$L_{1.0}$= 0.1724P2 - 0.8902	0.987	$L_{1.0}$= 0.3911P2 - 0.9413	0.988

Table 5.198: Inlet Pressure Vs Microtube Discharges of Various Diameter and Length of Microtubes
20 mm Lateral - 7 mm dia and 0.15 m Long Polytube - 2-Microtubes

	Avg. Discharges of One Microtube, lph								
P2	1.5-30	1.5-60	1.5-90	1.2-30	1.2-60	1.2-90	1.0-30	1.0-60	1.0-90
mwc	lph	lph	lph	lph	lph	lph	lph	lph	lph
14.50	51.60	43.86	36.12	49.20	41.82	34.44	48.00	40.80	33.60
14.00	50.40	42.84	35.28	48.00	40.80	33.60	46.80	39.78	32.76
13.50	47.99	40.80	33.60	45.59	38.76	31.92	44.39	37.74	31.08
13.00	46.24	39.30	32.37	43.84	37.26	30.69	42.64	36.24	29.85
12.50	46.00	39.10	32.20	43.60	37.06	30.52	42.40	36.04	29.68
12.00	45.76	38.89	32.03	43.36	36.85	30.35	42.16	35.83	29.51
11.50	45.37	38.56	31.76	42.97	36.52	30.08	41.77	35.50	29.24
11.00	45.04	38.28	31.53	42.64	36.24	29.85	41.44	35.22	29.01
10.50	43.10	36.63	30.17	40.70	34.59	28.49	39.50	33.57	27.65
10.00	41.16	34.98	28.81	38.76	32.94	27.13	37.56	31.92	26.29
9.50	40.68	34.57	28.47	38.28	32.53	26.79	37.08	31.51	25.95
9.00	40.25	34.21	28.18	37.85	32.17	26.50	36.65	31.15	25.66
8.50	39.92	33.93	27.94	37.52	31.89	26.26	36.32	30.87	25.42
8.00	39.50	33.57	27.65	37.10	31.53	25.97	35.90	30.51	25.13
7.50	38.30	32.55	26.81	35.90	30.51	25.13	34.70	29.49	24.29
7.00	36.36	30.90	25.45	33.96	28.86	23.77	32.76	27.84	22.93
6.50	33.68	28.62	23.57	31.28	26.58	21.89	30.08	25.56	21.05
6.00	30.99	26.34	21.70	28.59	24.30	20.02	27.39	23.28	19.18
5.50	29.79	25.32	20.86	27.39	23.28	19.18	26.19	22.26	18.34
5.00	28.59	24.30	20.02	26.19	22.26	18.34	24.99	21.24	17.50
4.50	27.39	23.28	19.18	24.99	21.24	17.50	23.79	20.22	16.66
4.00	26.19	23.57	20.96	23.79	21.41	19.04	22.59	20.33	18.08
3.50	25.44	22.89	20.35	23.04	20.73	18.43	21.84	19.65	17.47
3.00	24.53	22.08	19.63	22.13	19.92	17.71	20.93	18.84	16.75
2.50	21.85	19.67	17.48	19.45	17.51	15.56	18.25	16.43	14.60
2.00	18.43	16.59	14.75	16.03	14.43	12.83	14.83	13.35	11.87
1.50	15.01	13.51	12.01	12.61	11.35	10.09	11.41	10.27	9.13
1.00	11.13	10.02	8.90	8.73	7.86	6.98	7.53	6.78	6.02
11.00	36.43	32.79	29.15	34.03	28.93	23.82	32.83	27.91	22.98
10.50	35.51	31.96	28.41	33.11	28.14	23.17	31.91	27.12	22.33
10.00	34.49	31.04	27.59	32.09	27.28	22.46	30.89	26.26	21.62
9.50	34.01	30.61	27.21	31.61	26.87	22.13	30.41	25.85	21.29
9.00	33.29	30.96	28.63	30.89	26.26	21.62	29.69	25.24	20.78

Table 5.199: Inlet Pressure- Microtube Discharge Regression Equations for Various Diameter and Length of Microtubes 20 mm Lateral - 7 mm dia and 0.15 m Long Polytube - 2-Microtubes

Diameter of microtube	Length of microtube	Pressure-discharge equation	R^2	Estimated pressure for various discharges, mwc	
mm	m			20	10
1.5	0.3	$P2= 0.009q^{1.881}$	0.949	2.52	0.68
1.5	0.6	$P2= 0.008q^{1.992}$	0.961	3.12	0.79
1.5	0.9	$P2= 0.007q^{2.123}$	0.962	4.05	0.93
1.2	0.3	$P2= 0.020q^{1.693}$	0.947	3,19	0.99
1.2	0.6	$P2= 0.020q^{1.769}$	0.937	4.00	1.17
1.2	0.9	$P2= 0.020q^{1.873}$	0.917	5.47	1.49
1.0	0.3	$P2= 0.030q^{1.594}$	0.944	3.56	1.18
1.0	0.6	$P2= 0.031q^{1.662}$	0.935	4.50	1.42
1.0	0.9	$P2= 0.031q^{1.753}$	0.916	5.92	1.76

Table 5.200: Microtube Length - Inlet Pressure Regression Equations for Various Diameter of Microtubes 20 mm Lateral - 7 mm dia and 0.15 m long Polytube - 2 Microtubes

Diameter of microtube	Pressure -Length Equations			
mm	20 lph		10 lph	
	L	R^2	L	R^2
1.5	$L_{1.5}$ = 0.387P2 - 0.651	0.985	$L_{1.5}$ = 2.425P2 - 1.339	0.990
1.2	$L_{1.2}$ =0.256P2 - 0.481	0.973	$L_{1.2}$ = 0.302P2 - 1.361	0.991
1.0	$L_{1.0}$ =0.251P2 - 0.569	0.987	$L_{1.0}$ = 1.031P2 - 0.897	0.992

Tables 5.201 to 5.248 present inlet pressure vs microtube discharges of various diameter and length of microtubes, regression equations for inlet pressure- microtube discharge for various diameter and length of microtubes, and regression equations for microtube length - inlet pressure for various diameter of microtubes for 20 mm lateral - 7 mm polytube and 0.30 m, 0.45 m, 0,60 m, 0.75 m, & 0.90 m length of polytubes considering 2,3 and 4 microtubes respectively and are given in enclosed DVD.

5.2.2 Field experiments on crops

5.2.2.1 Summer groundnut

Crop water requirement of summer groundnut was 452.74 mm, 455.13 mm and 449.56 mm, against this water applied was 453.60 mm, 457.78 mm and 451.32 mm in years 2005, 2006 and 2007 respectively.

Cultivation cost and yield of summer groundnut are presented in Table 4.75 and 4.76 respectively.

Internal rate of return

Average yield of each year from four replications were determined. Average yield was considered for the calculation of internal rate of return of that year. IRR was also calculated considering mean yield of the three year.

Table 5.249 gives the internal rate of return by MIS for 0.60 m row spacing and 75 % of crop water requirement for summer groundnut in 2005.

Table 5.250 illustrates the internal rate of return by MIS for 0.60 m row spacing and 100 % of crop water requirement for summer groundnut in 2005, and is given in enclosed DVD.

Table 5.251 shows the internal rate of return by MIS for 0.60 m spacing and 125 % of crop water requirement for summer groundnut in 2005, and is given in enclosed DVD.

Table 5.252 give the internal rate of return by ITK MIS for 0.60 m row spacing and 75 % of crop water requirement for summer groundnut in 2005, and is given in enclosed DVD .

Table 5.253 illustrates the internal rate of return by ITK MIS for 0.60 m row spacing and 100 % of crop water requirement for summer groundnut in 2005 and is given in enclosed DVD.

Table 5.254 shows the internal rate of return by ITK MIS for 0.60 m row spacing and 125 % of crop water requirement for summer groundnut in 2005 and is given in enclosed DVD.

Table 5.255 gives the internal rate of return by MIS for 0.45 m row spacing and 75 % of crop water requirement for summer groundnut in 2005, and is given in enclosed DVD.

Table 5.256 illustrates the internal rate of return by MIS for 0.45 m row spacing and 100 % of crop water requirement for summer groundnut in 2005 and is given in enclosed DVD.

Table 5.257 shows the internal rate of return by MIS for 0.45 m spacing and 125 % of crop water requirement for summer groundnut in 2005 and is given in enclosed DVD.

Table 5.258 gives the internal rate of return by ITK MIS for 0.45 m row spacing and 75 % of crop water requirement for summer groundnut in 2005, and is given in enclosed DVD.

Table 5.259 illustrates the internal rate of return by ITK MIS for 0.45 m spacing and 100 % of crop water requirement for summer groundnut in 2005, and is given in enclosed DVD.

Table 5.260 shows the internal rate of return by ITK MIS for 0.45 m spacing and 125 % of crop water requirement for summer groundnut in 2005, and is given in enclosed DVD.

Tables 5.261 to 5.263 give the internal rate of return by MIS for 0.60 m crop spacing and 75 % , 100 % and 125 % of crop water requirement for summer groundnut in 2006 and are given in enclosed DVD.

Tables 5.264 to 5.266 illustrate the internal rate of return by ITK MIS for 0.60 m crop spacing and 75 %, 100 % and 125 % of crop water requirement for summer groundnut in 2006 and are given in enclosed DVD.

Tables 5.267 to 5.269 give the internal rate of return by MIS for 0.45 m crop spacing and 75 %, 100 % and 125 % of crop water requirement for summer groundnut in 2006 and are given in enclosed DVD.

Tables 5.270 to 5.272 indicate the internal rate of return by ITK MIS for 0.45 m crop spacing and 75 %, 100 % and 125 % of crop water requirement for summer groundnut in 2006, and are given in enclosed DVD.

Tables 5.273 to 5.275 illustrate the internal rate of return by MIS for 0.60 m crop spacing and 75 %, 100 % and 125 % of crop water requirement for summer groundnut in 2007 and are given in enclosed DVD.

Tables 5.276 to 5.278 show the internal rate of return by ITK MIS for 0.60 m spacing and 75 %, 100 % and 125 % of crop water requirement for summer groundnut in 2007 and given in enclosed DVD.

Tables 5.279 to 5.281 give the internal rate of return by MIS for 0.45 m crop spacing and 75 %, 100 % and 125 % of crop water requirement for summer groundnut in 2007, and are given in enclosed DVD.

Table 5.282 to Table 5.284 indicate the internal rate of return by ITK MIS for 0.45 m crop spacing and 75 %, 100 % and 125 % of crop water requirement for summer groundnut in 2007, and are given in enclosed DVD.

Table 5.285 illustrate the internal rate of return by MIS for 0.60 m crop spacing and 75 % of crop water requirement for summer groundnut considering the mean yield of the three year, and is given in enclosed DVD.

Tables 5.286 and 5.287 show the internal rate of return by MIS for 0.60 m crop spacing and 100 % and 125 % of crop water requirement for summer groundnut considering the mean yield and are enclosed in DVD.

Table 5.288 gives the internal rate of return by ITK MIS for 0.60 m crop spacing and 75 % of crop water requirement for summer groundnut considering the mean yield, and is given in enclosed DVD.

Tables 5.289 and 5.290 give the internal rate of return by ITK MIS for 0.60 m spacing and 100 % and 125 % of crop water requirement for summer groundnut considering the mean yield and are enclosed in DVD.

Table 5.291 gives the internal rate of return by MIS for 0.45 m crop spacing and 75 % of crop water requirement for summer groundnut considering the mean yield of 2005, 2006 and 2007, and is given in enclosed DVD.

Table 5.292 and 5.293 give the internal rate of return by MIS for 0.45 m crop spacing and 100 % and 125 % of crop water requirement for summer groundnut considering the mean yield of 2005, 2006 and 2007 and are enclosed in DVD.

Table 5.294 gives the internal rate of return by ITK MIS for 0.45 m crop spacing and 75 % of crop water requirement for summer groundnut considering the mean yield of 2005, 2006 and 2007, and is given in enclosed DVD.

Table 5.295 and 5.296 give the internal rate of return by ITK MIS for 0.45 m crop spacing and 100 % and 125 % of crop water requirement for summer groundnut considering the mean yield of 2005, 2006 and 2007 and are enclosed in DVD.

Table 5.297 shows the internal rate return considering average yield of summer groundnut grown in year 2005, 2006 and 2007 for different row spacing, irrigation depths and irrigation systems.

Table 5.249: Internal Rate of Return by MIS for 0.60 m spacing and 75 % of Crop Water Requirement for Summer Groundnut in Year 2005

Crop : Summer Groundnut — Crop Spacing : 0.15 m x 0.60 m — Yield = 21.03 qui/ha — Field Size 57.6 m x 28.8 m

SR. NO.		PARTICULARS		AMOUNT IN RS.									
				1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	8th year	9th year	10th year
1	20.18%	**CAPITAL COST**	94672.5										
2		**FIXED COST**											
a)		Depreciation		13529	23185	16558	11825	8454	8445	8454	4222	0	0
b)		Interest		8521	7303	5216	3726	2662	1901	1141	380	0	0
c)		Insurance		710	710	710	710	710	710	710	710	710	710
d)		Maintenance and repairs		473	473	947	1420	1893	2367	2367	2367	2367	2367
e)		Farm labourers' wages		11280	11280	11280	11280	11280	11280	11280	11280	11280	11280
f)		Operator's salary		500	500	500	500	500	500	500	500	500	500
3		**CASH OUTFLOW**		35013	43452	35211	29461	25500	25203	24452	19459	14857	14857
4		**NET CASH OUTFLOW**		21484	20266	18653	17636	17045	16758	15998	15237	14857	14857
5		**CULTIVATION COST**											
a)		Ploughing		600	600	600	600	600	600	600	600	600	600
b)		Cultivating		700	700	700	700	700	700	700	700	700	700
c)		Seeds		3854	3854	3854	3854	3854	3854	3854	3854	3854	3854
d)		Sowing		300	300	300	300	300	300	300	300	300	300
e)		Fertilizers and manures											
	i)	D.A.P.		485	485	485	485	485	485	485	485	485	485
	ii)	Farm yard manure		1600	1600	1600	1600	1600	1600	1600	1600	1600	1600
	iii)	Ryzobium culture		96	96	96	96	96	96	96	96	96	96
	iv)	Urea		50	50	50	50	50	50	50	50	50	50
	v)	Fertilizers and manures appl.		750	750	750	750	750	750	750	750	750	750
f)		Pesticides and herbicides											
	i)	Foret		1023	1023	1023	1023	1023	1023	1023	1023	1023	1023
	iii)	Pesticides and herbicides appl.		1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
g)		Energy cost		600	600	600	600	600	600	600	600	600	600
h)		Harvesting		1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
i)		Packing		330	330	330	330	330	330	330	330	330	330
j)		Transportation		464	464	464	464	464	464	464	464	464	464
		Total cultivation cost		13552	13552	13552	13552	13552	13552	13552	13552	13552	13552
6		**INCOME**											
a)		Yield of produce in quintal/ha		21.03	21.03	21.03	21.03	21.03	21.03	21.03	21.03	21.03	21.03
b)		Selling price Rs/quintal		2600	2600	2600	2600	2600	2600	2600	2600	2600	2600
c)		Income from produce		54678	54678	54678	54678	54678	54678	54678	54678	54678	54678
7		**CASH INFLOW**		41126	41126	41126	41126	41126	41126	41126	41126	41126	41126
8		**NET CASH FLOW**	-94673	19642	20860	22473	23490	24081	24368	25128	25889	26269	26269
9		**INTERNAL RATE OF RETURN**	20.18%										

Table 5.297: IRR Considering Yield of Summer Groundnut Grown in Year 2005, 2006 and 2007 at T.C.D. Farm, WREMI, Samiala

Irrigation Systems	Crop Spacings m	IRR considering yield of summer groundnut, %											
		2005			2006			2007			Mean		
		T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
MIS	B_1= 0.60	**20.18**	17.21	12.07	**27.42**	23.79	19.77	**29.11**	19.64	16.14	**25.67**	20.30	16.10
	B_2 = 0.45	**31.04**	24.49	19.70	**33.16**	25.85	19.74	**28.33**	23.44	14.13	**30.89**	24.63	17.94
ITK MIS	B_1= 0.60	**47.20**	46.25	37.54	**60.39**	54.22	47.90	**57.05**	48.26	40.53	**54.96**	49.65	42.09
	B_2 = 0.45	**60.73**	59.96	49.48	**72.30**	63.25	52.34	**63.28**	51.94	53.86	**65.49**	58.44	49.07

5.2.2.2 Cauliflower

Crop water requirement of cauliflower was 215.87 cm, 218.55 mm and 212.45 mm, against this water applied was 217.35 mm, 220.46 mm and 215.89 mm in years 2005, 2006 and 2007 respectively.

Cultivation cost and yield of cauliflower are presented in Table 4.81 and 4.82 respectively.

Internal rate of return

Average yield of each year from four replications were determined. Average yield was considered for the calculation of internal rate of return of that year. IRR was also calculated considering mean yield of the three year.

Table 5.298 gives the internal rate of return by MIS for 0.60 m row spacing and 75 % of crop water requirement for cauliflower in 2005.

Table 5.299 illustrates the internal rate of return by MIS for 0.60 m row spacing and 100 % of crop water requirement for cauliflower in 2005, and is given in enclosed DVD.

Table 5.300 shows the internal rate of return by MIS for 0.60 m row spacing and 125 % of crop water requirement for cauliflower in 2005, and is given given in enclosed DVD.

Table 5.301 gives the internal rate of return by ITK MIS for 0.60 m row spacing and 75 % of crop water requirement for cauliflower in 2005, and is given in enclosed DVD.

Table 5.302 illustrate the internal rate of return by ITK MIS for 0.60 m row spacing and 100 % of crop water requirement for cauliflower in 2005 and is given in enclosed DVD.

Table 5.303 shows the internal rate of return by ITK MIS for 0.60 m row spacing and 125 % of crop water requirement for cauliflower in 2005 and is given in enclosed DVD.

Table 5.304 gives the internal rate of return by MIS for 0.45 m row spacing and 75 % of crop water requirement for cauliflower in 2005, and is given in enclosed DVD.

Table 5.305 shows the internal rate of return by MIS for 0.45 m row spacing and 100 % of crop water requirement for cauliflower in 2005 and is given in enclosed DVD.

Table 5.306 shows the internal rate of return by MIS for 0.45 m row spacing and 125 % of crop water requirement for cauliflower in 2005, and is given in enclosed DVD.

Table 5.307 gives the internal rate of return by ITK MIS for 0.45 m row spacing and 75 % of crop water requirement for cauliflower in 2005, and is given in enclosed DVD.

Table 5.308 shows the internal rate of return by ITK MIS for 0.45 m row spacing and 100 % of crop water requirement for cauliflower in 2005, and are given in enclosed DVD.

Table 5.309 shows the internal rate of return by ITK MIS for 0.45 m row spacing and 125 % of crop water requirement for cauliflower in 2005, and are given in enclosed DVD.

Table 5.310 to Table 5.312 give the internal rate of return by MIS for 0.60 m row spacing and 75 % , 100 % and 125 % of crop water requirement for cauliflower in 2006 and are given in enclosed DVD.

Table 5.313 to Table 5.315 illustrate the internal rate of return by ITK MIS for 0.60 m row spacing and 75 %, 100 % and 125 % of crop water requirement for cauliflower in 2006 and are given in enclosed DVD.

Table 5.316 to 5.318 shows the internal rate of return by MIS for 0.45 m row spacing and 75 %, 100 % and 125 % of crop water requirement for cauliflower in 2006 and are in enclosed DVD.

Table 5.319 to 5.321 indicates the internal rate of return by ITK MIS for 0.45 m row spacing and 75 %, 100 % and 125 % of crop water requirement for cauliflower in 2006 and is given in enclosed DVD.

Table 5.322 to 5.324 give the internal rate of return by MIS for 0.60 m row spacing and 75 %, 100 % and 125 % of crop water requirement for cauliflower in 2007 and are given in enclosed DVD.

Table 5.325 to 5.327 illustrate the internal rate of return by ITK MIS for 0.60 m row spacing and 75 %, 100 % and 125 % of crop water requirement for cauliflower in 2007 and are given in enclosed DVD.

Table 5.328 to Table 5.330 shows the internal rate of return by MIS for 0.45 m row spacing and 75 %, 100 % and 125 % of crop water requirement for cauliflower in 2007 and are given in enclosed DVD.

Table 5.331 to Table 5.333 indicates the internal rate of return by ITK MIS for 0.45 m row spacing and 75 %, 100 % and 125 % of crop water requirement for cauliflower in 2007 and are given in enclosed DVD.

Table 5.334 gives the internal rate of return by MIS for 0.60 m row spacing and 75 % of crop water requirement for cauliflower considering the mean yield, and is given in enclosed DVD .

Table 5.335 and 5.336 indicate the internal rate of return by MIS for 0.60 m row spacing and 100 % and 125 % of crop water requirement for cauliflower considering the mean yield and are given in enclosed DVD.

Table 5.337 illustrate the internal rate of return by ITK MIS for 0.60 m row spacing and 75 % of crop water requirement for cauliflower considering the mean yield, and is given in enclosed DVD.

Table 5.338 and 5.339 show the internal rate of return by ITK MIS for 0.60 m row spacing and 100 % and 125 % of crop water requirement for cauliflower considering the mean yield and are given in enclosed DVD.

Table 5.340 gives the internal rate of return by MIS for 0.45 m row spacing and 75 % of crop water requirement for cauliflower considering the mean yield, and is given in enclosed DVD.

Table 5.341 and 5.342 show the internal rate of return by MIS for 0.45 m spacing and 100 % and 125 % of crop water requirement for cauliflower considering the mean yield and are given enclosed in DVD.

Table 5.343 illustrate the internal rate of return by ITK MIS for 0.45 m spacing and 75 % of crop water requirement for cauliflower considering the mean yield, and is given in enclosed DVD.

Table 5.344 and 5.345 give the internal rate of return by ITK MIS for 0.45 m spacing and 100 % and 125 % of crop water requirement for cauliflower considering the mean yield and are given in enclosed DVD.

Table 5.346 indicates the internal rate return considering average yield of cauliflower grown in year 2005, 2006 and 2007 for different row spacing, irrigation depths and irrigation systems.

Table 5.298: Internal Rate of Return by MIS for 0.60 m spacing and 75 % of Crop Water Requirement for Cauliflower in Year 2005

Crop : Cauliflower | Crop Spacing : 0.45 m x 0.60 m | Yield = 240.35 qui/ha | Field Size 57.6 m x 28.8 m

SR. NO.		PARTICULARS		AMOUNT IN RS. 1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	8th year	9th year	10th year
1	166.09%	**CAPITAL COST**	94672.5										
2		**FIXED COST**											
a)		Depreciation		13529	23185	16558	11825	8454	8445	8454	4222	0	0
b)		Interest		8521	7303	5216	3726	2662	1901	1141	380	0	0
c)		Insurance		710	710	710	710	710	710	710	710	710	710
d)		Maintenance and repairs		473	473	947	1420	1893	2367	2367	2367	2367	2367
e)		Farm labourers' wages		11280	11280	11280	11280	11280	11280	11280	11280	11280	11280
f)		Operator's salary		500	500	500	500	500	500	500	500	500	500
3		**CASH OUTFLOW**		35013	43452	35211	29461	25500	25203	24452	19459	14857	14857
4		**NET CASH OUTFLOW**		21484	20266	18653	17636	17045	16758	15998	15237	14857	14857
5		**CULTIVATION COST**											
a)		Ploughing		600	600	600	600	600	600	600	600	600	600
b)		Cultivating		700	700	700	700	700	700	700	700	700	700
c)		Seeds		1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
d)		Sowing		300	300	300	300	300	300	300	300	300	300
e)		Fertilizers and manures											
	i)	Farm yard manure		1600	1600	1600	1600	1600	1600	1600	1600	1600	1600
	ii)	Ammonium Sulphate		500	500	500	500	500	500	500	500	500	500
	iii)	Fertilizers and manures appl.		750	750	750	750	750	750	750	750	750	750
f)		Pesticides and herbicides											
	i)	Foret		960	960	960	960	960	960	960	960	960	960
	ii)	Rogor		63	63	63	63	63	63	63	63	63	63
	iii)	Monocrotophos		350	350	350	350	350	350	350	350	350	350
	iv)	fenvalenete		300	300	300	300	300	300	300	300	300	300
	v)	Pesticides and herbicides appl.		1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
g)		Energy cost		377	377	377	377	377	377	377	377	377	377
h)		Harvesting		1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
i)		Packing		1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
j)		Transportation		2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
		Total cultivation cost		14300	14300	14300	14300	14300	14300	14300	14300	14300	14300
6		**INCOME**											
a)		Yield of produce in quintal/ha		240.35	240.35	240.35	240.35	240.35	240.35	240.35	240.35	240.35	240.35
b)		Selling price Rs/quintal		800	800	800	800	800	800	800	800	800	800
c)		Income from produce		192280	192280	192280	192280	192280	192280	192280	192280	192280	192280
7		**CASH INFLOW**		177980	177980	177980	177980	177980	177980	177980	177980	177980	177980
8		**NET CASH FLOW**	-94673	156496	157714	159327	160344	160935	161222	161982	162743	163123	163123
9		**INTERNAL RATE OF RETURN**	166.09%										

Table 5.346: IRR of Cauliflower Grown in Year 2005, 2006 and 2007 at T.C.D. Farm, WREMI, Samiala

Irrigation Systems	Crop Spacings m	IRR considering yield of cauliflower, %											
		2005			2006			2007			Mean		
		T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
MIS	B_1= 0.60	**166.09**	164.75	117.55	**127.21**	123.78	119.41	**222.87**	179.47	140.54	**172.03**	155.99	125.83
	B_2 = 0.45	**159.05**	141.00	139.43	**117.82**	111.06	106.84	**225.29**	207.57	143.13	**167.35**	153,18	129.79
ITK MIS	B_1= 0.60	**325.52**	300.06	246.87	**250.81**	247.72	238.80	**499.18**	307.23	384.55	**359.28**	285.00	290.05
	B_2 = 0.45	**328.27**	283.63	211.41	**241.43**	221.75	219.17	**572.12**	443.42	347.62	**380.56**	316.25	259.38

5.2.2.3 Summer groundnut and cauliflower

Two crops, summer groundnut and cauliflower were grown in a year. IRR was calculated and analysis of variance was carried out for the year.

Internal rate of return (Two season crops)

Internal rate of return for a year was calculated considering yield of summer groundnut and cauliflower. Two crops could be grown in a year using both irrigation systems. IRR was also calculated considering the mean yield of crops of the three years..

Table 5.347 gives the internal rate of return by MIS for 0.60 m row spacing and 75% of crop water requirement for summer groundnut and cauliflower in 2005.

Table 5.348 illustrate the internal rate of return by MIS for 0.60 m row spacing and 100% of crop water requirement for summer groundnut and cauliflower in 2005, and is given in enclosed DVD.

Table 5.349 shows the internal rate of return by MIS for 0.60 m row spacing and 125% of crop water requirement for summer groundnut and cauliflower in 2005, and is given in enclosed DVD.

Table 5.350 gives the internal rate of return by ITK MIS for 0.60 m row spacing and 75% of crop water requirement for summer groundnut and cauliflower in 2005, and is given in enclosed DVD.

Table 5.351 illustrate the internal rate of return by ITK MIS for 0.60 m row spacing and 100% of crop water requirement for summer groundnut and cauliflower in 2005, and is given in enclosed DVD.

Table 5.352 shows the internal rate of return by ITK MIS for 0.60 m row spacing and 125% of crop water requirement for summer groundnut and cauliflower in 2005, and is enclosed in DVD.

Table 5.353 indicate the internal rate of return by MIS for 0.45 m row spacing and 75% of crop water requirement for summer groundnut and cauliflower in 2005, and is given in enclosed DVD.

Table 5.354 shows the internal rate of return by MIS for 0.45 m row spacing and 100% of crop water requirement for summer groundnut and cauliflower in 2005, and is given in enclosed DVD.

Table 5.355 gives the internal rate of return by MIS for 0.45 m row spacing and 125% of crop water requirement for summer groundnut and cauliflower in 2005, and is given in enclosed DVD.

Table 5.356 illustrate the internal rate of return by ITK MIS for 0.45 m row spacing and 75% of crop water requirement for summer groundnut and cauliflower in 2005, and is given in enclosed DVD.

Table 5.357 indicate the internal rate of return by ITK MIS for 0.45 m row spacing and 100% of crop water requirement for summer groundnut and cauliflower in 2005 and is given in enclosed DVD.

Table 5.358 shows the internal rate of return by ITK MIS for 0.45 m row spacing and 125% of crop water requirement for summer groundnut and cauliflower in 2005 and is given in enclosed DVD.

Table 5.359 to 5.361 give the internal rate of return by MIS for 0.60 m row spacing and 75%, 100% and 125% of crop water requirement for summer groundnut and cauliflower in 2006 and are given in enclosed DVD.

Table 5.362 to 5.364 give the internal rate of return by ITK MIS for 0.60 m row spacing and 75%, 100% and 125% of crop water requirement for summer groundnut and cauliflower in 2006 and are given in enclosed DVD.

Table 5.365 to 5.367 show the internal rate of return by MIS for 0.45 m row spacing and 75%, 100% and 125% of crop water requirement for summer groundnut and cauliflower in 2006 and are given in enclosed DVD.

Table 5.368 to 5.370 indicates the internal rate of return by ITK MIS for 0.45 m row spacing and 75%, 100% and 125% of crop water requirement for summer groundnut & cauliflower in 2006 and are given in enclosed DVD.

Table 5.371 to Table 5.373 illustrate the internal rate of return by MIS for 0.60 m row spacing and 75%, 100% and 125% of crop water requirement for summer groundnut and cauliflower in 2007 and are given in enclosed DVD.

Table 5.374 to Table 5.376 give the internal rate of return by ITK MIS for 0.60 m row spacing and 75%, 100% and 125% of crop water requirement for summer groundnut and cauliflower in 2007 and are given in enclosed DVD.

Table 5.377 to Table 5.379 indicates the internal rate of return by MIS for 0.45 m row spacing and 75%, 100% and 125% of crop water requirement for summer groundnut and cauliflower in 2007 and are given in enclosed DVD.

Table 5.380 to Table 5.382 indicates the internal rate of return by ITK MIS for 0.45 m row spacing and 75%, 100% and 125% of crop water requirement for summer groundnut and cauliflower in 2007 and are given in enclosed DVD.

Table 5.383 gives the internal rate of return by MIS for 0.60 m row spacing and 75% of crop water requirement for summer groundnut and cauliflower considering the mean yield, and is given in enclosed DVD.

Table 5.384 and 5.385 indicate the internal rate of return by MIS for 0.60 m row spacing and 100% and 125% of crop water requirement for summer groundnut and cauliflower considering the mean yield and are enclosed in DVD.

Table 5.386 gives the internal rate of return by ITK MIS for 0.60 m row spacing and 75% of crop water requirement for summer groundnut and cauliflower considering the mean yield, and is given in enclosed DVD.

Table 5.387 and Table 5.388 give the internal rate of return by ITK MIS for 0.60 m row spacing and 100% and 125% of crop water requirement for summer groundnut and cauliflower considering the mean yield and are enclosed in DVD.

Table 5.389 gives the internal rate of return by MIS for 0.45 m row spacing and 75% of crop water requirement for summer groundnut and cauliflower considering the mean yield, and is given in enclosed DVD.

Table 5.390 and 5.391 illustrate the internal rate of return by MIS for 0.45 m row spacing and 100% and 125% of crop water requirement for summer groundnut and cauliflower considering the mean yield and are given in enclosed DVD.

Table 5.392 shows the internal rate of return by ITK MIS for 0.45 m row spacing and 75% of crop water requirement for summer groundnut and cauliflower considering the mean yield, and is given in enclosed DVD.

Table 5.393 and Table 5.394 give the internal rate of return by ITK MIS for 0.45 m row spacing and 100% and 125% of crop water requirement for summer groundnut and cauliflower considering the mean yield and are given in enclosed DVD.

Table 5.395 shows the internal rate return considering average yield of summer groundnut and cauliflower grown in year 2005, 2006 and 2007 for different row spacing, irrigation depths and irrigation systems.

Table 5.347: Internal Rate of Return by MIS for 0.60 m Spacing and 75 % of Crop Water Requirement for Summer Groundnut and Cauliflower in Year 2005

Crop : Combination of Groundnut and Cauliflower **Field Size 57.6 m x 28.8 m**

SR. NO.		PARTICULARS		AMOUNT IN RS.									
				1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	8th year	9th year	10th year
1	100.40%	**CAPITAL COST**	189345										
2		**FIXED COST**											
a)		Depreciation		27057	46371	33116	23649	16909	16890	16909	8445	0	0
b)		Interest		17041	14606	10433	7452	5324	3802	2282	760	0	0
c)		Insurance		1420	1420	1420	1420	1420	1420	1420	1420	1420	1420
d)		Maintenance and repairs		947	947	1893	2840	3787	4734	4734	4734	4734	4734
e)		Farm labourers' wages		11280	11280	11280	11280	11280	11280	11280	11280	11280	11280
f)		Operator's salary		500	500	500	500	500	500	500	500	500	500
3		**CASH OUTFLOW**		58245	75123	58643	47142	39219	38625	37124	27139	17934	17934
4		**NET CASH OUTFLOW**		31188	28753	25526	23492	22311	21736	20216	18694	17934	17934
5		**CULTIVATION COST**											
a)		Cultivation cost of Groundnut		13552	13552	13552	13552	13552	13552	13552	13552	13552	13552
b)		Cultivation cost of Cauliflower		14300	14300	14300	14300	14300	14300	14300	14300	14300	14300
		Total cultivation cost		27852	27852	27852	27852	27852	27852	27852	27852	27852	27852
6		**INCOME**											
a)		Yield of produce of Groundnut in quintal/ha		21.03	21.03	21.03	21.03	21.03	21.03	21.03	21.03	21.03	21.03
b)		Selling price of Groundnut Rs/quintal		2600	2600	2600	2600	2600	2600	2600	2600	2600	2600
c)		Yield of produce of Cauliflower in quintal/ha		240.35	240.35	240.35	240.35	240.35	240.35	240.35	240.35	240.35	240.35
d)		Selling price of Cauliflower Rs/quintal		800	800	800	800	800	800	800	800	800	800
e)		Total Income from produce		246958	246958	246958	246958	246958	246958	246958	246958	246958	246958
7		**CASH INFLOW**		219106	219106	219106	219106	219106	219106	219106	219106	219106	219106
8		**NET CASH FLOW**	-189345	187918	190353	193580	195614	196795	197370	198890	200412	201172	201172
9		**INTERNAL RATE OF RETURN**	**100.40%**										

Table 5.395: IRR Considering Yield of Summer Groundnut and Cauliflower Grown in Year 2005, 2006 and 2007 at T.C.D. Farm WREMI, Samiala

Irrigation Systems	Crop Spacings m	IRR considering yield of summer groundnut and cauliflower, %											
		2005			2006			2007			Mean		
		T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
MIS	B_1= 0.60	**100.40**	98.48	72.82	**84.18**	80.84	76.91	**132.72**	106.90	86.01	**107.24**	93.23	80.65
	B_2 = 0.45	**100.47**	88.49	85.62	**80.86**	74.12	69.32	**132.29**	121.27	85.22	**106.61**	97.67	77.65
ITK MIS	B_1= 0.60	**197.99**	184.82	154.09	**167.21**	162.62	155.07	**289.22**	189.48	224.31	**226.27**	175.21	188.58
	B_2 = 0.45	**203.95**	181.29	140.13	**166.39**	152.06	145.37	**327.07**	257.17	206.00	**245.49**	204.95	175.79

5.3 Analysis

5.3.1 Indoor ITK MIS laboratory work

Friction head loss in ITK MIS

With reference to Tables 4.11 to 4.70, pressures at 16 nodes on lateral were measured. Head loss through each section between two pressure gauges between two outlets, Hf_{Li} was determined. Hf_{li} is head loss through minor length near outlet, as pressure gauges could not be placed exactly at outlet. Hf_{li} was very negligible compared to Hf_{Li}. So head loss measured at both sides of outlet by pressure transducers was same as head loss at outlet. Head losses in polytubes were also determined.

Head loss at outlets by regression analysis

Regression equations were developed for 20 mm lateral for one microtube and are presented in Table 5.1. Discrepancy ratio, D is very near to 1 for 1st to 6th outlets, which reflects less discrepancy in observed and predicted data. D value is more than 1 for 7thand 8th outlet, which reflects that model over predict the data. Coefficient of correlation r is also above 0.65 for all the outlets. R^2 value of the models varies from 0.34 to 0.65.

Difference in RMSE value for model and prediction is less which reflects less deviation in observed and predicted head loss.

Table 5.2 gives regression equations for 20 mm lateral for two microtubes attached to micromanifold. Discrepancy ratio D is very near to 1 for all outlets except 4th and 5th outlet. This reflects that the equation exactly predicts the measured rate. Value of R^2 varies from 0.33 to 0.61. Value of r varies from 0.57 to 0.78 which indicates good correlation between observed and predicted values.

Regression equations for 20 mm lateral for three microtubes are presented in Table 5.3. Value of D is 1 for model and validation for 1st outlet which indicates equation exactly predicts the measured data. At other outlets value of D is not one which indicates predicted head loss may differ from observed head loss.

Table 5.4 presents regression equations for 20 mm lateral for four microtubes. D is very near to 1 for all outlets except 1st and 6th outlet, which reveals that an equation exactly predicts the measured data at other outlets. Value of r varies from 0.52 to 0.87.

There are the explanations for not getting the value of D as 1 in Table 5.2, 5.3 and 5.4 for all the outlets.

Tables 5.5, 5.6 and 5.7 indicate regression equations for 16 mm lateral for 1, 2, and 3 microtubes. Value of D is near one for all outlets which represents that predicted head loss are near to observed head loss.

Tables 5.8, 5.9 and 5.10 indicate regression equations for 12 mm lateral for 1, 2, and 3 microtubes. Value of D is near to one for all outlets which represents that predicted head loss and observed head loss are similar.

In ITK MIS, Polytubes are attached to laterals using jointers. Jointers are inserted in to lateral. There may be small variation in size of jointers. Due to this there may be variation in discharge at particular outlet.

The head loss increased with increase in protrusion areas, which may differ from outlet to outlet.

Regression equations were developed using 70 % of data and remaining 30 % data were used for validation. Selections of this 70 % of data were done through random selection. Numbers of trials were carried out to choose good model which would give value of D near to one. Sometimes model over or under predict the data as per the random selection of dataset.

Head loss through polytubes by regression analysis

Regression equations to determine head loss through polytubes for 20 mm lateral when one microtube is attached is given in Table 5.11. Value of D is very near to one in all outlets. Coefficient of correlation r varies from 0.53 to

0.75, which shows good correlation between predicted and observed head loss in polytube. R^2 varies from 0.34 to 0.56.

Table 5.12 presents regression equations to determine head loss through polytubes for two microtubes. D value is very near to one for all the outlets. Correlation coefficienr r varies from 0.39 to 0.69.

Table 5.13 indicates that value of D is very near to one for all the oulets. Value of r varies from 0.62 to 0.68, which reveals good correlation between predicted and observed head loss.

With reference to Table 5.14, D value is very near to1 for all outlets except 8^{th} outlet, which reveals that predicted head loss is same as observed head loss. For 8^{th} outlets model under predict the head loss.

Tables 5.15 to 5.17 present regression equations for 16 mm lateral for 1, 2, & 3 microtubes. D value is near 1 in all outlets. This represents that equation exactly predicts the measured head loss. R^2 value varies from 0.47 to 0.63 for one microtube, 0.34 to 0.62 for two microtubes and 0.47 to 0.61 for 3 microtubes. The coefficient of correlation r varies from 0.69 to 0.79 which shows good correlation between observed and predicted head loss.

Tables 5.18 to 5.20 illustrate regression equations for 12 mm lateral for 1, 2, & 3 microtubes. D value is near one in all outlets. This reveals that predicted head loss in polytubes are same as observed headloss. The coefficient of correlation varies from 0.49 to 0.63 for one microtube, 0.31 to 0.49 for two microtube and 0.21 to 0.58 for three microtubes.

In ITK MIS, Polytubes were attached to laterals on one side and with manifold to other side using jointers. There might be small variation in size of jointers. Due to this there might be variation in discharge at particular outlet.

F factor for ITK MIS

Table 5.21 and Fig. 5.1 give F factor for 20 mm lateral – 4 mm dia and 0.15 m long polytube for 2 , 3, and 4 microtubes for various inlet pressures.

Fig. 5.1 illustrate the variation in F factor with respect to no. of outlets on laterals. For two and three microtubes, variations of F factor with respect to no.of outlets are similar. The F factors for 4 microtubes are higher compared to that for two and three microtubes due to increase in discharge. Head loss is more due to increased discharge and hence F factor increases.

The number outlets which receive water depends on pressure and discharge available. So the number of outlets served for given lateral inlet discharge for 2, 3 and 4 microtubes are varying. Hence in Table 5.21, number of outlets and F values are not the same for 2,3 and 4 microtubes.

Fig. 5.2 shows variation in F factor w.r.t. number of outlets for 20 mm lateral – 4 mm dia and 0.30 m long polytube – 2, 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD.

With respect to Fig. 5.2 variation in F factor along the lateral is similar for two and three microtubes. F factor with respect to no. of outlets for four microtubes are higher compared to that for two and three microtubes.

Fig. 5.3 shows variation in F factor w.r.t. number of outlets for 20 mm lateral – 4 mm dia and 0.45 m long polytube – 2, 3, and 4 microtubes for various inlet pressures and is given in enclosed DVD .

It is observed from Fig.5.3 that the value of F factor with respect to no.of outlets for four microtubes is higher than that for two and three microtubes.

Fig. 5.4 shows variation in F factor w.r.t. number of outlets for 20 mm lateral – 4 mm dia and 0.60 m long polytube – 2, 3 and 4 microtubes for various inlet pressures. It is observed that F factor w. r. t to no. of outlets is comparatively higher than that for two and three microtubes and is given in enclosed DVD.

Figs. 5.5 and 5.6 illustrate variation in F factor w.r.t. number of outlets for 20 mm lateral – 4 mm dia and 0.75 m and 0.90 m long polytube – 2, 3 and 4 microtubes for various inlet pressures. Variations of F factor w.r.t. no. of outlets are similar for two, three and four microtubes. Fig. 5.6 is given in enclosed DVD.

Figs. 5.7, 5.8, 5.10 and 5.11 illustrate variation of F factor for 20 mm – 5 mm dia and 0.15 m, 0.30, 0.60 and 0.75 m long polytube – 2, 3 & 4 microtubes for various inlet pressures. Value of F is high in 4 microtubes in few cases, compared to 2 and 3 microtubes.

Figs. 5.9 and 5.12 depict variation of F factor for 20 mm – 5 mm dia and 0.45 m, 0.60 m , 0.75 m and 0.90 m long polytube - 2, 3 & 4 microtubes for various inlet pressures. Variation of F factor w.r.t. number of outlets are similar but no specific pattern can be observed to compare F factor between 2, 3 or 4 microtubes. Figs. 5.8 to 5.12 are given in enclosed DVD.

Figs. 5.13 to 5.18 depict variation of F factor for 20 mm – 6 mm dia and 0.15, 0.30, 0.45 m, 0.60 m and 0.75 m and 0.90 m long polytube - 2, 3 & 4 microtubes for various inlet pressures. Variation of F factor is similar for 2, 3 and 4 microtubes. Figs. 5.14 to 5.18 are given in enclosed DVD.

Fig. 5.19, 5.20, and 5.21 illustrate variation of F factor w. r. t. to no. of outlets for 20 mm lateral – 7 mm dia and 0.15 m, 0.30 m and 0.45 m long polytube for 2, 3 & 4 microtubes. F factor is higher in 4 microtubes compared to 2 and 3 microtubes. Figs. 5.20 and 5.21 are given in enclosed DVD.

Figs. 5.22, 5.23, and 5.24 present variation of F factor w. r. t. to no. of outlets for 20 mm lateral – 7 mm dia and 0.60 m, 0.75 m and 0.90 m long polytube for 2, 3 & 4 microtubes. The variation in F value value is similar for 1, 2 & 3 microtubes and are given in enclosed DVD.

Fig. 5.1: Variation of F factor w.r.t to no. of outlets for 20 mm lateral - 4 mm dia and 0.15 m long polytube for 2 ,3, and 4 microtubes for various inlet pressures

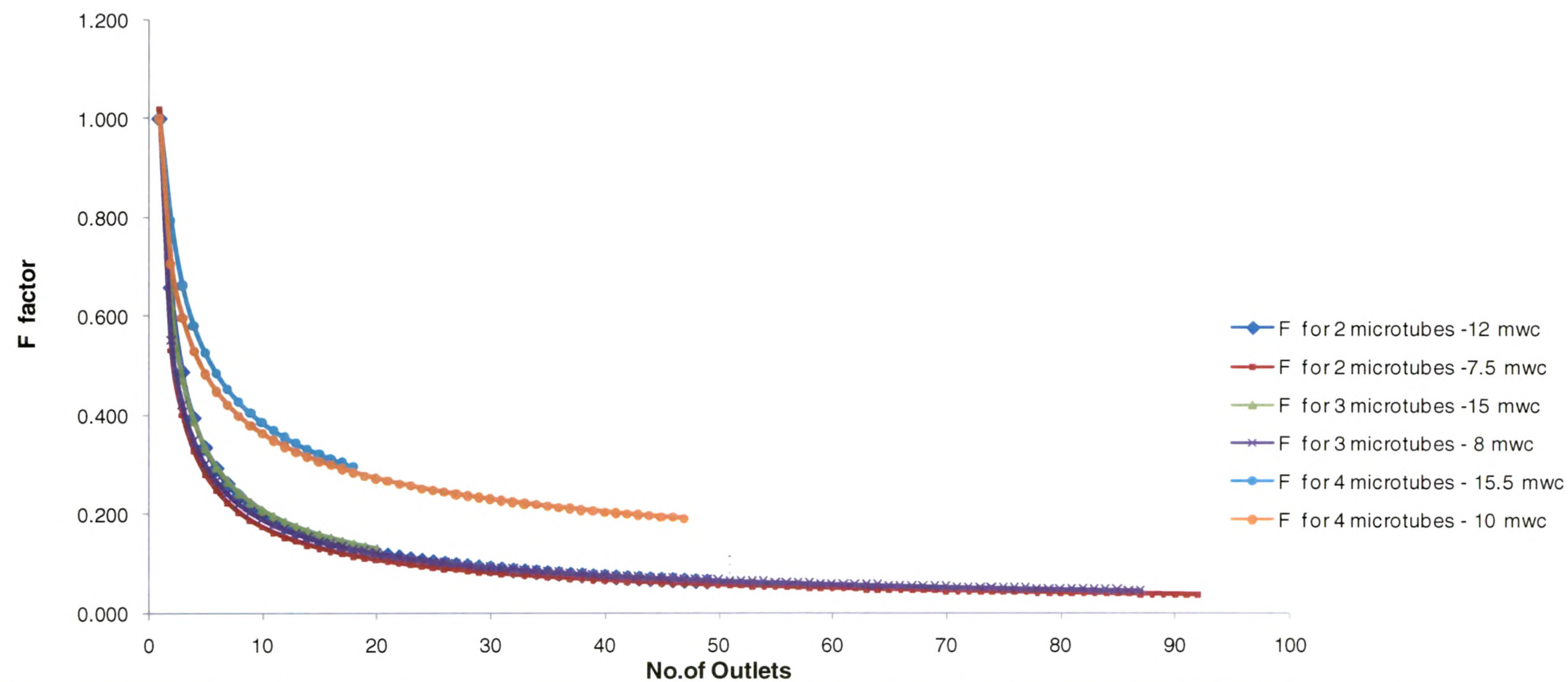
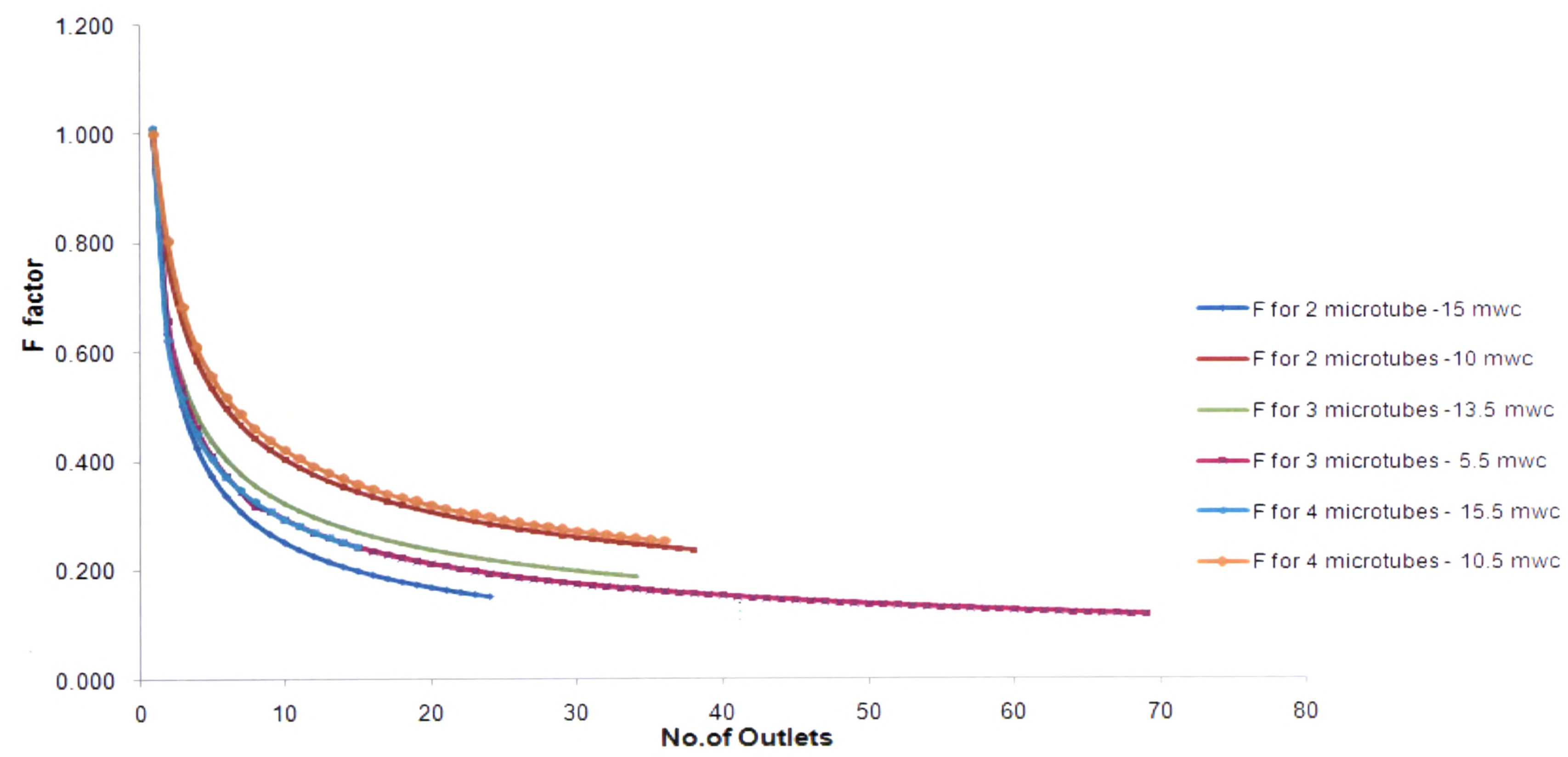


Fig. 5.7: Variation of F factor w.r.t to no. of outlets for 20 mm lateral - 5 mm dia and 0.15 m long polytube for 2 ,3, and 4 microtubes for various inlet pressures



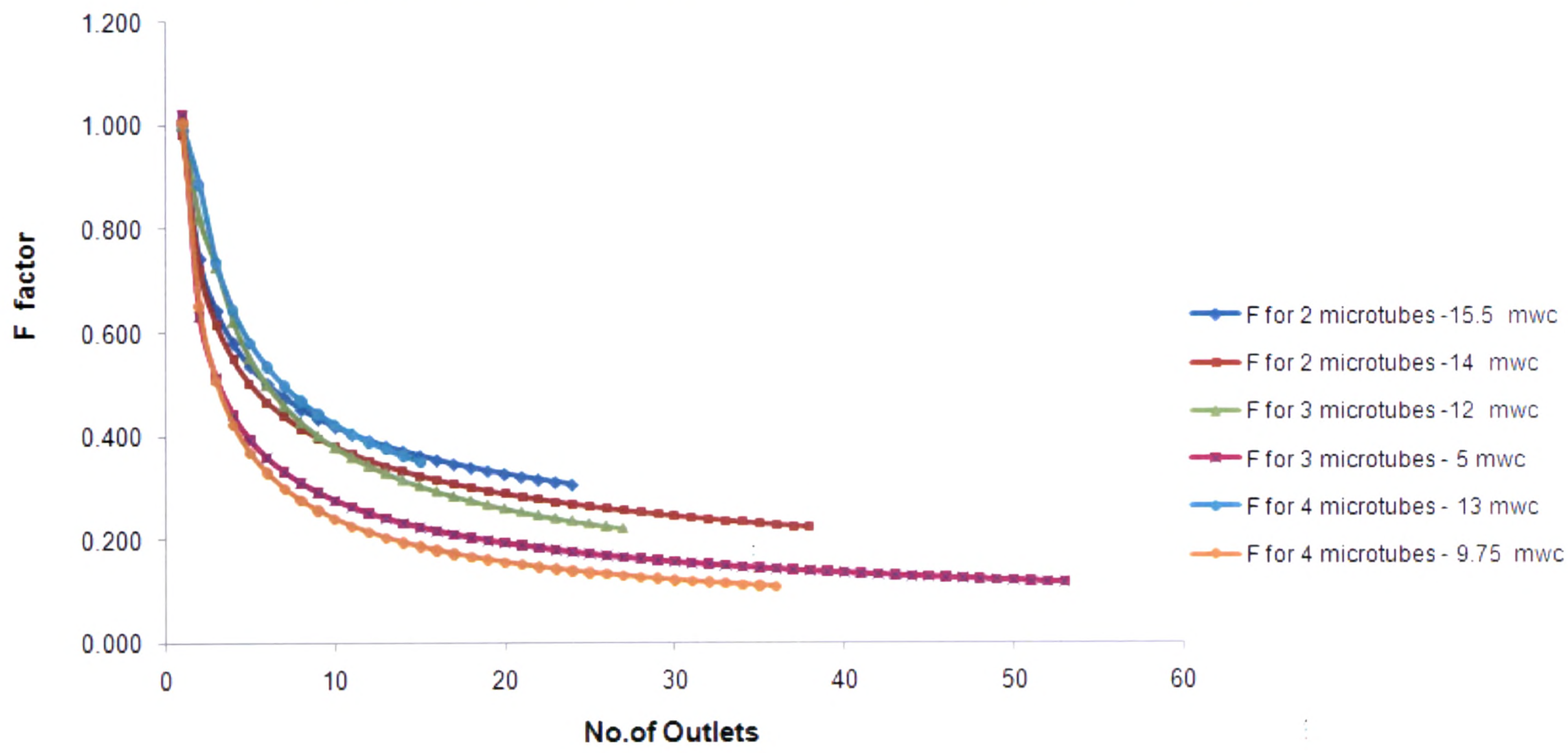
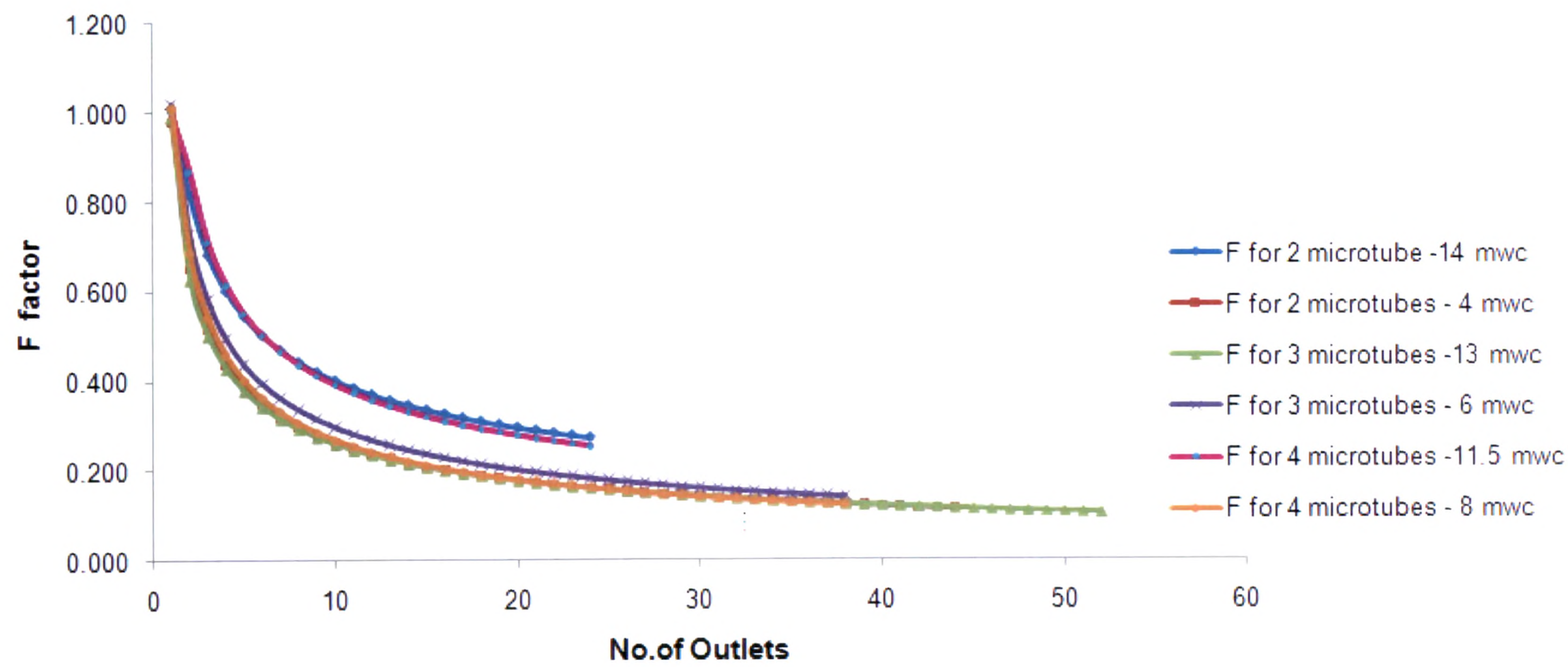


Fig. 5.13: Variation of F factor w.r.t to no. of outlets for 20 mm lateral - 6 mm dia and 0.15 m long polytube for 2 ,3, and 4 microtubes for various inlet pressures

Fig. 5.19: Variation of F factor w.r.t to no. of outlets for 20 mm lateral - 7 mm dia and 0.15 m long polytube for 2 ,3, and 4 microtubes for various inlet pressures



Discharge through various outlets depends on number of microtubes attached to the micromanifold. Discharge was higher for four microtubes compared to two and three microtubes. Due to high discharge head loss was also high in case of four microtubes. Hence value of F factor was higher in 4 microtubes compared to 2 and 3 microtubes.

To analyze the effect of no.of microtubes on F factor, graphs were developed for each length of polytube, i.e. 0.15 m, 0.30 m, 0.45 m, 0.60 m and 0.90 m .

For each length of polytube, a combined F factor graph for 4 mm, 5 mm, 6 mm and 7 mm diameter polytube was developed and analyzed.

Fig. 5.229 illustrates variation of F factor w.r.t. to no. of outlets for 20 mm lateral - 4 mm, 5 mm, 6 mm, & 7 mm and 0.15 m long polytube - 2, 3, & 4 – microtubes.

F factor depends on no.of microtubes attached. For 4, 5 and 6 mm diameter polytube F factor increase with increase in no. of microtubes. For 7 mm diameter polytube, F factor for 4 microtube is lower than 2 and 3 microtubes.

Fig. 5.230 presents variation of F factor w.r.t. to no. of outlets for 20 mm lateral - 4 mm, 5 mm, 6 mm, & 7 mm and 0.30 m long polytube - 2, 3, & 4 – microtubes and is given in enclosed DVD.

For all the polytubes, F factor increases with increase in no. of microtubes.

Fig. 5.231 presents variation of F factor w.r.t. to no. of outlets for 20 mm lateral - 4 mm, 5 mm, 6 mm, & 7 mm and 0.45 m long polytube - 2, 3, & 4 – microtubes and is given in enclosed DVD.

For 4, 6 and 7 mm diameter polytube, F factor increases with increase in no. of microtubes. For 5 mm reverse trend for F factor is observed.

Fig. 5.229 Variation of F factor w.r.t. to no. of outlets for 20 mm lateral - 4 mm, 5 mm, 6 mm, & 7 mm dia and 0.15 m long polytube - 2, 3, & 4 - microtubes

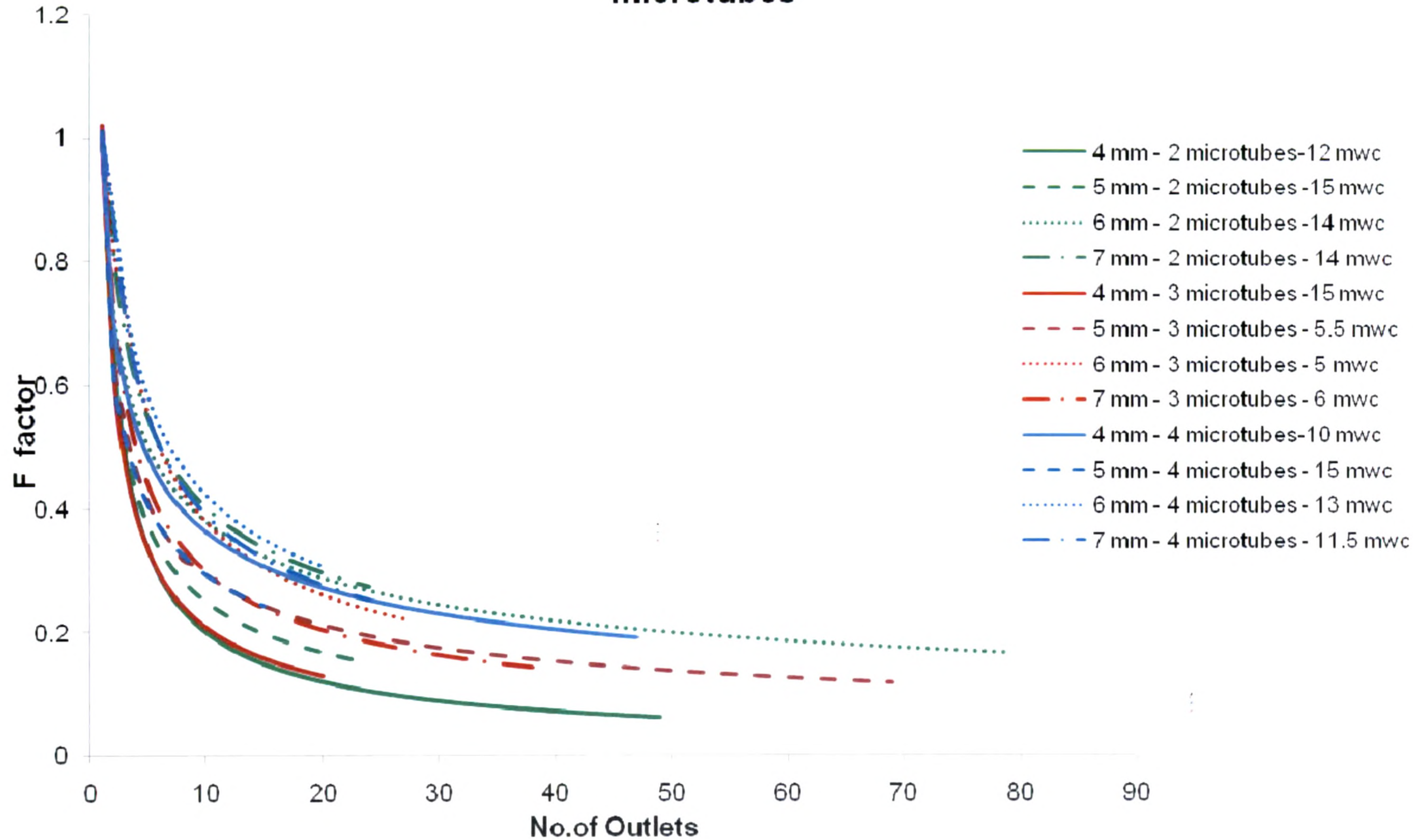


Fig. 5.232 presents variation of F factor, w.r.t. to no. of outlets for 20 mm lateral - 4 mm, 5 mm, 6 mm, & 7 mm and 0.60 m long polytube - 2, 3, & 4 – microtubes and is given in enclosed DVD.

For 4, 5 and 6 mm diameter polytube, F factor increases with increase in no. of microtubes. For 7 mm, F factor is higher for 2 microtube, followed by 4 and 3 microtubes.

Fig. 5.233 presents variation of F factor w.r.t. to no. of outlets for 20 mm lateral - 4 mm, 5 mm, 6 mm, & 7 mm and 0.75 m long polytube - 2, 3, & 4 – microtubes and is given in enclosed DVD.

For 5, 6 and 7 mm diameter polytube, F factor increase with increase in no. of microtubes. For 4 mm, F factor is higher for 4 microtube, followed by 2 and 3 microtubes.

Fig. 5.234 shows variation of F factor w.r.t. to no. of outlets for 20 mm lateral - 4 mm, 5 mm, 6 mm, & 7 mm and 0.90 m long polytube - 2, 3, & 4 – microtubes and is given in enclosed DVD.

For 5 and 6 mm diameter polytube, F factor increase with increase in no. of microtubes. For 4 mm, F factor is higher for 4 microtube, followed by 2 and 3 microtubes, however the variation is very less. For 7 mm polytube, F factor is higher for 4 microtube, followed by 2 and 3 microtubes.

As discussed above, in almost all cases of polytube diameters (4 mm, 5 mm, 6mm and 7 mm) the F factor increases with increase in no.of microtubes because of increased discharge. However, in some of the cases the sequence is not followed. The reason is explained below.

Limitation of F factor analysis

The F factor was obtained using experimental data. Only those data were considered for the analysis where the F factor at the first outlet is 1.0. Such no. of data were less and were at different inlet pressure.

The F factor analysis graphs were developed using those data which have more or less same inlet pressure. Though, in some cases due to unavailability of same inlet pressure data, variations in trends of F factors were observed.

Development of the relationship between inlet pressure - microtube discharge and length of microtubes – inlet pressure

The relationship between inlet pressures and discharge through microtubes were established.

Fig. 5.25 shows relationship between Inlet pressure and microtube discharge of various diameter and length of microtubes for 20 mm lateral - 4 mm dia and 0.15 m long polytube - 2-microtubes.

With reference to Fig. 5.25 and Table 5.37 regression equations were obtained which show relationship of inlet pressure vs discharge through microtubes. For a given discharge inlet pressure required in lateral was determined using these regression equations.

Fig. 5.26 and Table 5.38 give microtube length-inlet pressure relationship for various diameter and length of microtubes. The regression equations were developed for discharge of 15 lph.

Fig. 5.27 indicates microtube length-inlet pressure relationship for various diameter and length of microtubes. The regression equations were developed for 10 lph.

Regression equations to determine length of microtubes can be developed for various discharges. These equations were very useful in deciding the length of microtube required to obtain specific discharge in the field.

From Table 5.37 it reveals that for discharge 15 lph, estimated pressure for various diameter and length of microtube varies from 5.45 mwc to 20.05 mwc. Similarly, for discharge of 10 lph, estimated pressure for various combination ranges from 1.92 mwc to 7.75 mwc.

For each combination, regression equations are developed and are to be used to design ITK MIS.

Figs. 5.28 to 5.75 illustrate relationship between Inlet pressure and microtube discharge of various diameter and length of microtubes, microtube length-inlet pressure relationship for various diameter and length of microtubes for 20 mm lateral - 4 mm dia and 0.15 m, 0.30 m, 0.45 m, 0.60 m, 0.75 m and 0.90 m long polytube – 2, 3, & 4 – microtubes and are given in enclosed DVD.

Figs. 5.76 to 5.123 show relationship between Inlet pressure and microtube discharge of various diameter and length of microtubes, microtube length-inlet pressure relationship for various diameter and length of microtubes for 20 mm lateral - 5 mm dia and 0.15 m, 0.30 m, 0.45 m, 0.60 m, 0.75 m and 0.90 m long polytube – 2, 3, & 4 – microtubes and are given in enclosed DVD.

Figs. 5.124 to 5.177 give relationship between Inlet pressure and microtube discharge of various diameter and length of microtubes, microtube length-inlet pressure relationship for various diameter and length of microtubes for 20 mm lateral - 6 mm dia and 0.15 m, 0.30 m, 0.45 m, 0.60 m, 0.75 m and 0.90 m long polytube – 2, 3, & 4 – microtubes and are given in enclosed DVD.

Figs. 5.178 to 5.228 give relationship between Inlet pressure and microtube discharge of various diameter and length of microtubes, microtube length-inlet pressure relationship for various diameter and length of microtubes for 20 mm lateral - 7 mm dia and 0.15 m, 0.30 m, 0.45 m, 0.60 m, 0.75 m and 0.90 m long polytube – 2, 3, & 4 – microtubes and are given in enclosed DVD.

Fig. 5.25: Inlet pressure vs microtube discharge of various diameter and length of microtubes 20 mm lateral - 4 mm dia and 0.15 m long polytube - 2-microtubes

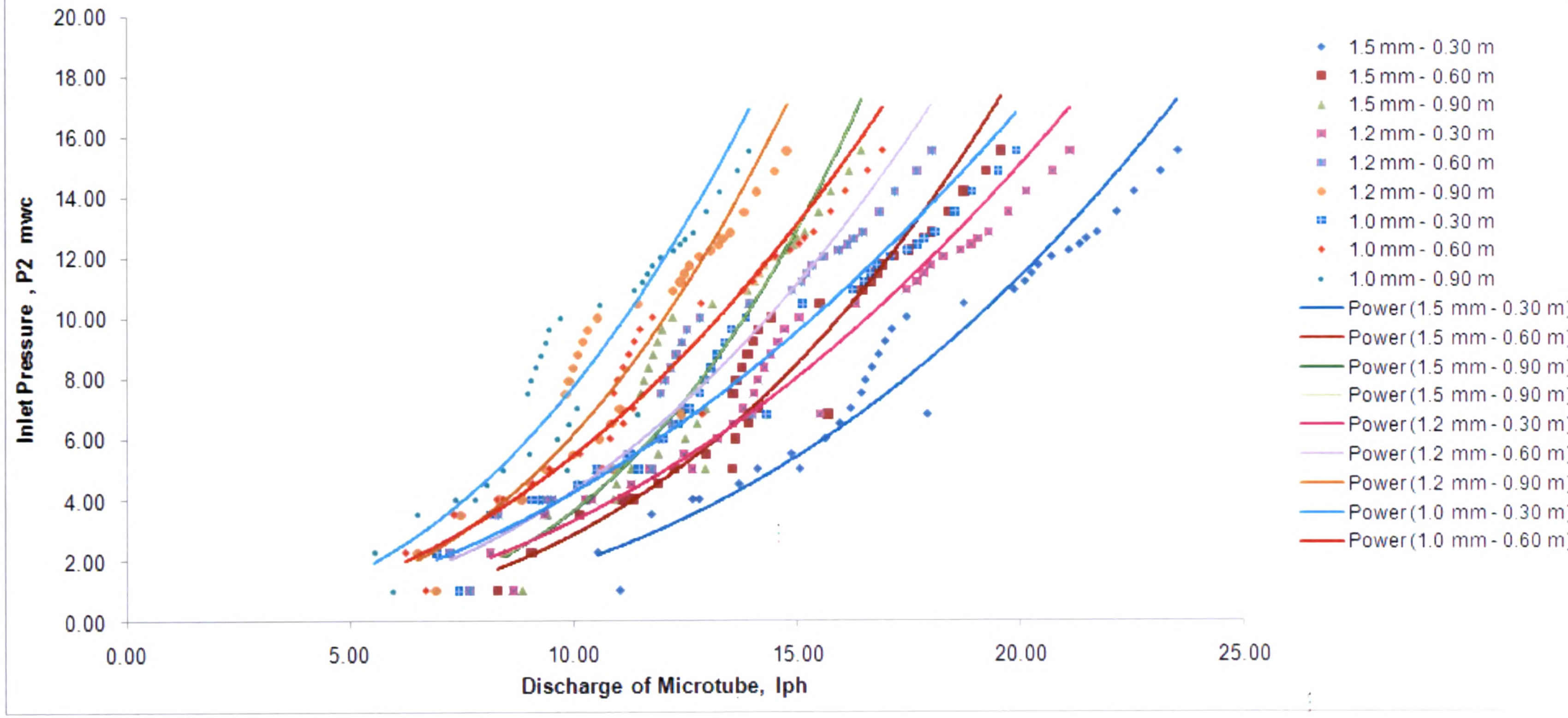


Fig. 5.26: Microtube length-inlet pressure relationship for various diameter and length of microtubes for microtube discharge 15 lph
20 mm dia lateral - 4 mm dia and 0.15 m polytube - 2 microtubes

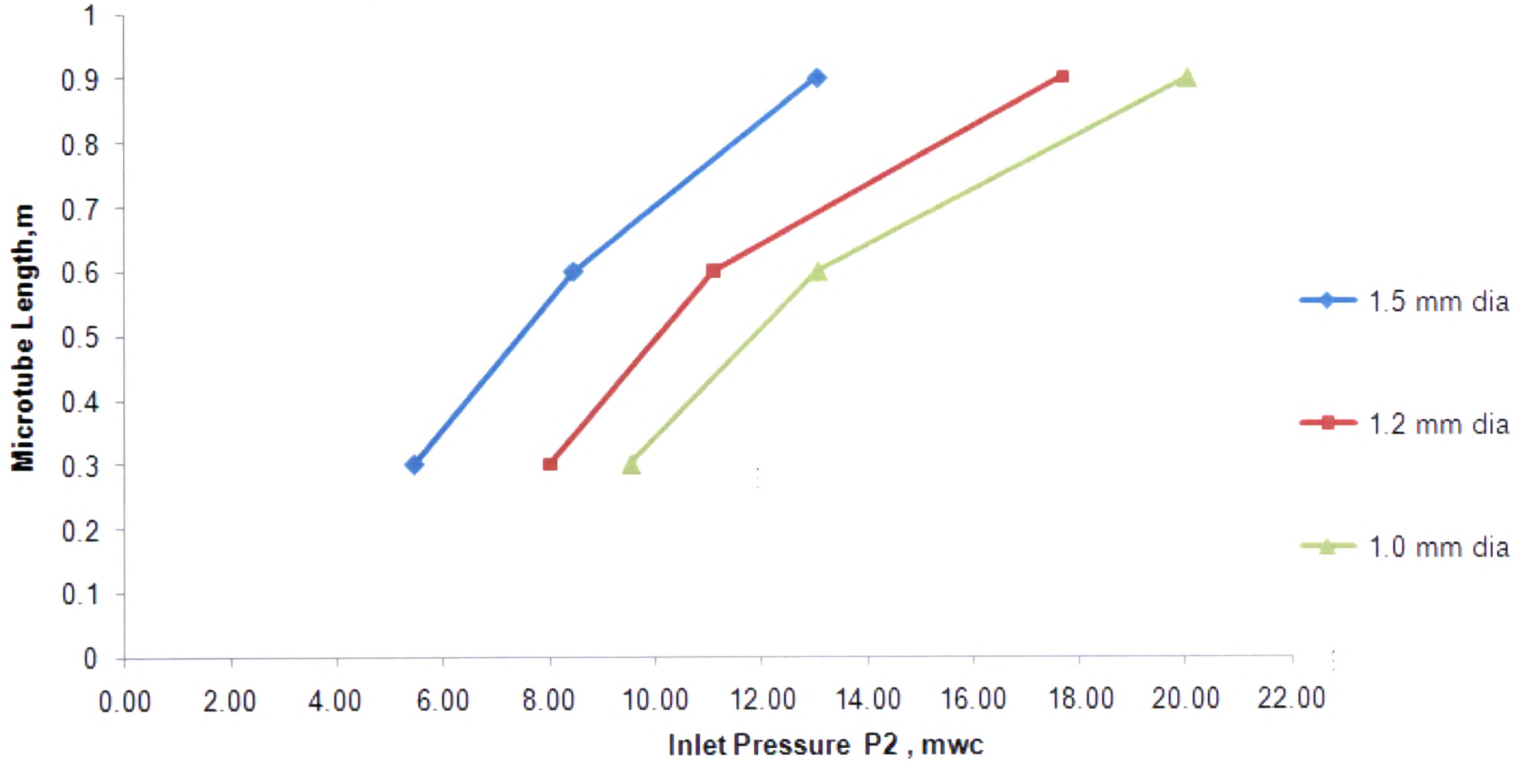
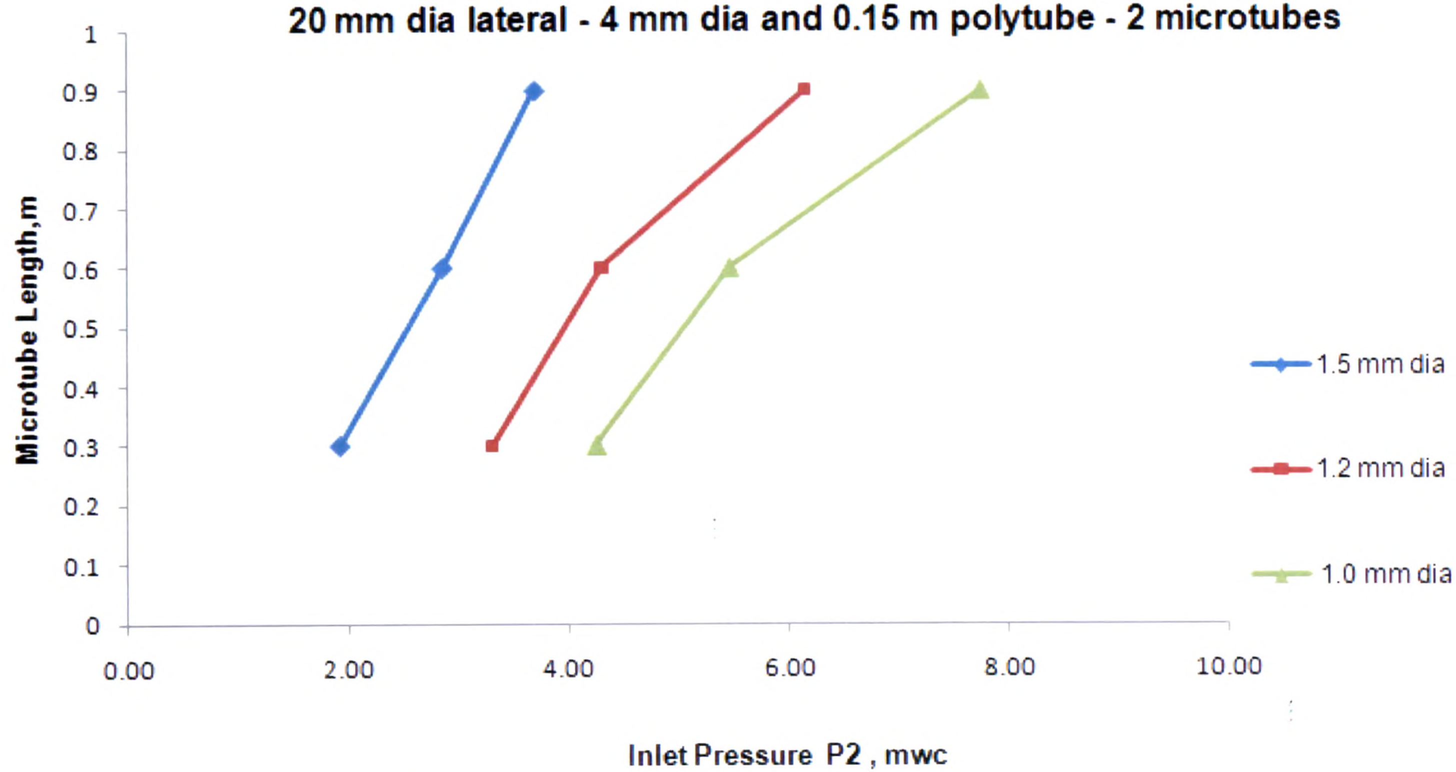


Fig. 5.27: Microtube length-inlet pressure relationship for various diameter and length of microtubes for microtube discharge 10 lph
20 mm dia lateral - 4 mm dia and 0.15 m polytube - 2 microtubes



5.3.2 Field experimental work

5.3.2.1 Summer groundnut

Analysis of variance

Analysis of variance on yield of summer groundnut

Effects of row spacings, irrigation depths and irrigation systems on yield of summer groundnut at T.C.D. Farm, WREMI, Samiala in 2005, 2006 and 2007 were analyzed as follows.

Factor	Level 1	Level 2	Level 3
A : Row Spacings	0.60 m	0.45 m	
B : Irrigation Depth	0.75 ETc	1.00 ETc	1.25 ETc
C : Irrigation Systems	MIS	ITK MIS	

Yield data presented in Table 4.76 were rearranged in Table 5.396.

Table 5.396: Effects of Row Spacings, Irrigation Depths and Irrigation Systems on Yield of Summer Groundnut at T.C.D. Farm, WREMI, Samiala in 2005, 2006 and 2007

Level of factors			Expected Yield of summer groundnut, quintal/ha			
A	B	C	2005	2006	2007	Total
1	1	1	21.03	23.37	23.98	68.38
1	1	2	20.59	23.10	22.50	66.18
1	2	1	20.11	22.18	20.91	63.20
1	2	2	20.41	21.92	20.83	63.15
1	3	1	18.60	20.90	19.83	59.33
1	3	2	18.79	20.72	19.38	58.88
2	1	1	28.41	29.31	27.30	85.02
2	1	2	26.06	28.77	26.69	81.52
2	2	1	25.67	26.22	25.28	77.17
2	2	2	25.88	26.65	24.06	76.59
2	3	1	23.75	23.76	21.67	69.18
2	3	2	23.47	24.11	22.49	70.07
Total			**272.74**	**291.01**	**274.90**	**838.65**

The analysis of the data were carried out by treating the experiment as a two way classification with a·b·c treatments and r replicates.

$C = (838.65)^2 / 36$

$= 19536.82$

$SST = (21.03)^2 + (20.59)^2 + ... + (22.49)^2 - 19536.82$

$= 297.6613$

SS(Tr)= 1/3 [$(68.38)^2 + (66.18)^2 + ... + (70.07)^2$] –19536.82

= 267.0898

SSR = 1/12 [$(272.74)^2 + (291.01)^2 + (274.90)^2$] – 19536.82

= 16.6147

SSE = SST – SS(Tr) – SSR

= 297.6613– 267.0898– 16.6147

= 13.9567

Next, the treatment sum of squares could be subdivided into the three main effect sums of squares, SSA, SSB and SSC, the three two way interaction sums of squares, SS(AB), SS(AC) and SS(BC) and the three way interaction sum of squares SS(ABC). To facilitate the calculation of these sums of squares following three tables were constructed.

		B			
		1	2	3	Total
A	1	134.5575	126.3500	118.2100	379.1175
	2	166.5350	153.7500	139.2425	459.5275
Total		301.0925	280.1000	257.4525	838.6450

		C		
		1	2	Total
A	1	190.9000	188.2175	379.1175
	2	231.3550	228.1725	459.5275
Total		422.2550	416.3900	838.6450

		C		
		1	2	Total
B	1	153.3900	147.7025	301.0925
	2	140.3625	139.7375	280.1000
	3	128.5025	128.9500	257.4525
Total		422.2550	416.3900	838.6450

To calculate SSA, SSB and SS(AB), refer to the first of the above tables and the treatment sum of squares is calculated as

$$rc\sum_{i=1}^{a} \sum_{j=1}^{b} (yij ... - y ...)^2 = 1/rc\sum_{i=1}^{a} \sum_{j=1}^{b} Tij^2.. - C ... \quad ... (5.1)$$

$=1/6[(134.55)^2+(166.53)^2+..... +(139.24)^2]$ – 19536.82

= 264.03

$SSA = 1/bcr \sum_{i=1}^{a} \quad T^2i.. - C$ ... ... (5.2)

= 1/18 [(379.11)2 + (459.52)2] – 19536.82

= 179.6047

$SSB = 1/acr \sum_{i=1}^{b} \quad T^2j.. - C$ ... ... (5.3)

= 1/12 [(301.09)2 + (280.1000)2 + (257.45)2] – 19536.82

= 79.3901

SS(AB) = 264.03 – 179.6047 – 79.3901

= 5.0359

Some calculations for the second table,

Treatment sum of squares

$= 1/9\ [(190.90)^2 + (231.3550)^2 + ... + (228.17)^2] - 19536.82$

= 180.5671201

SSC $= 1/18\ [(422.25)^2 + (416.39)^2] - 19536.82$

= 0.9555

SS(AC) = 180.5671201 –179.6047– 0.9555

= 0.0069

The analysis of third table yields the treatment sum of squares

$= 1/6\ [(153.39)^2 + (140.3625)^2 + ... + (128.95)^2] - 19536.82$

= 82.1350

SS(BC) = 82.1350– 79.3901– 0.9555

= 1.7894

The three way interaction sum of squares,

SS(ABC) = S (Tr) – SSA – SSB – SSC – SS(AB) – SS(AC) – SS(BC)

= 267.08–179.60 –79.39– 0.9555- 5.0359– 0.0069 –1.7894

= 0.3074

The degree of freedom for each main effect is one less than the number of levels of the corresponding factor. The degree of freedom for each interaction is the product of the degrees of freedom for those factors appearing in the interaction. The degree of freedom for the three main effects are 1, 2, 1 while the degree of freedom for the two way interactions are 2 ,1, 2 and degrees of freedom for the three way interactions is 2.

Table 5.397: Complete Analysis of Variance for Effect of Row Spacing, Irrigation Depths and Irrigation Systems on Yield of Summer Groundnut at T.C.D. Farm, WREMI, Samiala in 2005, 2006 and 2007

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	F	$F_{0.05}$ & $F_{0.01}$ from literature	Significance
Replicates	2	81069.58	40534.79	30.86	3.32/5.39	S
Main Effects						
A	1	20901.11	20901.11	15.91	4.17/7.56	S
B	2	22784.64	11392.32	8.67	3.32/5.39	S
C	1	1209.12	1209.12	0.92	4.17/7.56	N
Two way Interactions						
AB	2	1172.69	586.34	0.44	3.32/5.39	N
AC	1	8.7149	8.7149	0.00	4.17/7.56	N
BC	2	1123.19	561.59	0.42	3.32/5.39	N
Three way Interactions						
ABC	2	1147.11	573.56	0.43	3.32/5.39	N
Error	22	28890.15	1313.18			
Total	35	158306.33				

Obtaining the appropriate values of $F_{0.05}$ and $F_{0.01}$ from the literature, it was found that the test for replicates, factor A and factor B were significant at both the levels, while test of factor C was insignificant at both the levels. Two factor interactions AB, AC and BC were not significant at both the levels. Similarly, three factor interactions were not significant at both the levels.

It is concluded that the variations in the row spacings and irrigation depths affect the yield of summer groundnut and irrigation systems did not affect the yield of summer groundnut. Combination of row spacings, irrigation depths and irrigation systems did not affect the yield.

Analysis of variance on IRR of summer groundnut

Effects of row spacings, irrigation depths and irrigation systems on IRR of summer groundnut at T.C.D. Farm, WREMI, Samiala in 2005, 2006 and 2007 were analyzed as follows:

Factor	Level 1	Level 2	Level 3
A : Row Spacing	0.60 m	0.45 m	
B : Irrigation Depth	0.75 ETc	1.00 ETc	1.25 ETc
C : Irrigation Systems	MIS	ITK MIS	

Internal rate of Return for summer groundnut are given in Table 5.398.

Table 5.398: Effects of Row Spacings, Irrigation Depths and Irrigation Systems on IRR of Summer Groundnut at T.C.D. Farm, WREMI, Samiala grown in 2005, 2006 and 2007

Level of factors			Internal Rate of Return based on yield data, %			
A	**B**	**C**	**2005**	**2006**	**2007**	**Total**
1	1	1	20.18	27.42	29.11	76.71
1	1	2	47.20	60.39	57.05	164.63
1	2	1	17.21	23.79	19.64	60.64
1	2	2	46.25	54.22	48.26	148.73
1	3	1	12.07	19.77	16.14	47.97
1	3	2	37.54	47.90	40.53	125.98
2	1	1	31.04	33.16	28.33	92.53
2	1	2	60.73	72.30	63.28	196.30
2	2	1	24.49	25.85	23.44	73.77
2	2	2	59.96	63.25	51.94	175.15
2	3	1	19.70	19.74	14.13	53.58
2	3	2	49.48	52.34	53.86	155.68
Total			**427.67**	**500.19**	**425.85**	**500.12**

The degree of freedom for each main effect is one less than the number of levels of the corresponding factor. The degree of freedom for each interaction is the product of the degrees of freedom for those factors appearing in the interaction. The degree of freedom for the three main effects are 1, 2, 1 while the degree of freedom for the two way interactions are 2 ,1, 2 and degrees of freedom for the three way interactions is 2.

Table 5.402 shows the complete analysis of variance.

Table 5.399: Complete Analysis of Variance for Effect of Row Spacings, Irrigation Depths and Irrigation Systems on IRR of Summer Groundnut at T.C.D. Farm, WREMI, Samiala in 2005, 2006 and 2007

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	F	$F_{0.05}/F_{0.01}$ from literature	Significance
Replicates	2	246.4400	123.2200	12.1876	3.32/5.39	S
Main Effects						
A	1	415.8103	415.8103	41.1274	4.17/7.56	S
B	2	900.1723	450.0861	44.5176	3.32/5.39	S
C	1	8750.5979	8750.5979	865.5132	4.17/7.56	S
Two way Interaction						
AB	2	6.3660	3.1830	0.3148	3.32/5.39	N
AC	1	78.7354	78.7354	7.7876	4.17/7.56	N
BC	2	6.2947	3.1473	0.3113	3.32/5.39	N
Three way Interaction						
ABC	2	5.3131	2.6565	0.2628	3.32/5.39	N
Error	22	222.4266	10.1103			
Total	2	5.3131	2.6565	0.2628	3.32/5.39	N

Obtaining the appropriate values of $F_{0.05}$ and $F_{0.01}$ from the literature, it was found that the tests for replicates, factor A, factor B and factor C were significant at both the levels. Two factor interactions AB, AC and BC were not significant at both levels. Similarly, three factor interactions were not significant at both the levels.

It was concluded that the variations in the row spacing, irrigation depths and irrigation systems affected the IRR of summer groundnut. Combination of row spacings, irrigation depths and irrigation systems did not affect the IRR of summer groundnut.

5.3.2.2 Cauliflower

Analysis of variance

Analysis of variance on yield of cauliflower

As discussed earlier, similarly the effects of row spacings, irrigation depths and irrigation systems on yield of cauliflower at T.C.D. Farm, WREMI, Samiala in 2005, 2006 and 2007 were analyzed.

Factor	Level 1	Level 2	Level 3
A : Row Spacings	0.60 m	0.45 m	
B : Irrigation Depth	0.75 ETc	1.00 ETc	1.25 ETc
C : Irrigation Systems	MIS	ITK MIS	

Table 5.400 shows yield of cauliflower for various level of factors.

Table 5.400: Effects of Row Spacings, Irrigation Depths and Irrigation Systems on Yield of Cauliflower at T.C.D. Farm, WREMI, Samiala in 2005, 2006 and 2007

Level of factors			Expected yield of cauliflower, quintal/ha			
A	B	C	2005	2006	2007	Total
1	1	1	240.35	194.10	307.76	742.21
1	1	2	242.39	195.58	350.58	788.55
1	2	1	238.76	190.02	256.25	685.03
1	2	2	226.44	193.64	230.93	651.01
1	3	1	182.60	184.81	209.96	577.37
1	3	2	193.11	188.05	279.35	660.51
2	1	1	283.32	221.63	382.23	887.18
2	1	2	289.79	223.63	475.41	988.84
2	2	1	256.33	211.50	355.80	823.63
2	2	2	255.79	208.63	377.46	841.88
2	3	1	253.98	205.18	259.51	718.67
2	3	2	200.74	206.66	304.53	711.93
Total			**2863.59**	**2423.42**	**3789.78**	**9076.79**

The analysis of the data were carried out by treating the experiment as a two way classification with a·b·c treatments and r replicates.

$C = (9076.79)^2 / 36$
$= 2288558.8$

$SST = (240.35)^2 + (194.10)^2 + \ldots\ldots + (304.53)^2 - 2288558.8$
$= 158306.3319$

$SS(Tr) = 1/3\ [(742.21)^2 + (788.55)^2 + \ldots\ldots + (711.93)^2] - 2288558.8$
$= 48346.59762$

$SSR = 1/12\ [(2863.59)^2 + (2423.42)^2 + (3789.78)^2] - 2288558.8$
$= 81069.5814$

SSE = SST – SS (Tr) – SSR

= 158306.3319 – 48346.59762 – 81069.5814

= 28890.1529

Next, the treatment sum of squares could be subdivided into the three main effect sums of squares, SSA, SSB and SSC, the three two way interaction sums of squares, SS(AB), SS(AC) and SS(BC) and the three way interaction sum of squares SS(ABC). To facilitate the calculation of these sums of squares following three tables were constructed.

		B			
		1	2	3	Total
A	1	1530.7600	1336.0428	1237.8758	4104.6785
	2	1876.0138	1665.5061	1430.5916	4972.1115
Total		3406.7738	3001.5489	2668.4673	9076.7900

		C		
		1	2	Total
A	1	2004.6088	2100.0698	4104.6785
	2	2429.4690	2542.6425	4972.1115
Total		4434.0777	4642.7123	9076.7900

		C		
		1	2	Total
B	1	1629.3889	1777.3849	3406.7738
	2	1508.6540	1492.8948	3001.5489
	3	1296.0347	1372.4326	2668.4673
Total		4434.0777	4642.7123	9076.7900

To calculate SSA, SSB and SS(AB), refer to the first of the above tables and the treatment sum of squares is calculated as

$$rc\sum_{i=1}^{a} \sum_{j=1}^{b} (yij ... - y ...)^2 = 1/rc\sum_{i=1}^{a} \sum_{j=1}^{b} Tij^2.. - C... \quad (5.4)$$

=1/6[(1530.7600)2 + (1876.0138)2+..... + (1430.5916)2] – 2288558.

= 44858.44788

$$SSA = 1/bcr \sum_{i=1}^{a} T^2i.. - C \quad ... \quad ... \quad (5.5)$$

= 1/18 [(4104.6785)2 + (4972.1115)2] – 2288558.8

= 20901.1106

$SSB = 1/acr \sum_{i=1}^{b} T^2 j.. - C$ ... ... (5.6)

= 1/12 [(3406.7738)2 + (3001.5489)2 + (2668.4673)2] – 2288558.8

= 22784.6411

SS(AB) = 44858.44788 – 20901.1106 – 22784.6411

= 1172.6962

Performing the same calculations for the second of the tables

Treatment sum of squares

= 1/9 [(2004.6088)2 + (2429.4690)2 + ... + (2542.6425)2] – 2288558.8

= 22118.94744

SSC = 1/18 [(4434.0777)2 + (4642.7123)2] – 2288558.8

= 20901.1106

SS(AC) = 22118.94744–20901.1106– 20901.1106

= 8.7149

The analysis of third table yields the treatment sum of squares

= 1/6 [(1629.3889)2 + (1508.6540)2 + ... + (1372.4326)2] – 2288558.8

= 25116.9560

SS(BC) = 25116.9560– 22784.6411– 20901.1106

= 1123.1930

The three way interaction sum of squares

SS(ABC) = SS (Tr) – SSA – SSB – SSC – SS(AB) – SS(AC) – SS(BC)

= 48346.59762 – 20901.1106 – 22784.6411 – 20901.1106-
1172.6962– 8.7149–1123.1930

= 1147.1199

The degree of freedom for each main effect is one less than the number of levels of the corresponding factor. The degree of freedom for each interaction is the product of the degrees of freedom for those factors appearing in the interaction. The degree of freedom for the three main effects are 1, 2, 1 while the degree of freedom for the two way interactions are 2 ,1, 2 and degrees of freedom for the three way interactions is 2. Table 5.401 give complete analysis if variance for cauliflower for year 2005,2006, and 2007.

Table 5.401: Complete Analysis of Variance for Effect of Row Spacing, Irrigation Depths and Irrigation Systems on Yield of Cauliflower at T.C.D. Farm, WREMI, Samiala in 2005, 2006 and 2007

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	F	$F_{0.05}$ & $F_{0.01}$ from literature	Significance
Replicates	2	81069.58	40534.79	30.86	3.32/5.39	S
Main Effects						
A	1	20901.11	20901.11	15.91	4.17/7.56	S
B	2	22784.64	11392.32	8.67	3.32/5.39	S
C	1	1209.12	1209.12	0.92	4.17/7.56	N
Two way Interactions						
AB	2	1172.69	586.34	0.44	3.32/5.39	N
AC	1	8.71	8.71	0.00	4.17/7.56	N
BC	2	1123.19	561.59	0.42	3.32/5.39	N
Three way Interactions						
ABC	2	1147.11	573.56	0.43	3.32/5.39	N
Error	22	28890.15	1313.18			
Total	35	158306.33				

Obtaining the appropriate values of $F_{0.05}$ and $F_{0.01}$ from the literature, it was found that the test for replicates was significant at 0.05 and 0.01 levels. The tests for factor A and factor B were significant at both the levels, while test of factor C was insignificant at both the levels. Two factor interactions, AB, AC and BC were insignificant at both the levels. Similarly, three factor interactions were not significant at both the levels.

It was concluded that the variations in the row spacings and irrigation depths affected the yield of cauliflower and irrigation systems did not affect the yield of cauliflower. Other interactions did not affect the yield.

Analysis of variance on IRR of cauliflower

Analysis of variance reflects the effects of row spacings, irrigation depths and irrigation systems on IRR of cauliflower. Table 5.17 shows IRR for three years at various level of factors.

Factor	Level 1	Level 2	Level 3
A : Row Spacings	0.60 m	0.45 m	
B : Irrigation Depth	0.75 ETc	1.00 ETc	1.25 ETc
C : Irrigation Systems	MIS	ITK MIS	

Internal Rate of Return for cauliflower is given in Table 5.402

Table 5.402: Effects of Row Spacings, Irrigation Depths and Irrigation Systems on IRR of Cauliflower at T.C.D. Farm, WREMI, Samiala in 2005, 2006 and 2007

Level of factors			Internal Rate of Return, %			
A	B	C	2005	2006	2007	Total
1	1	1	166.09	127.21	223.00	516.30
1	1	2	326.69	250.81	499.18	1076.68
1	2	1	164.75	123.78	179.47	468.01
1	2	2	300.06	247.72	307.23	855.01
1	3	1	117.55	119.41	140.54	377.49
1	3	2	246.87	238.80	384.55	870.21
2	1	1	159.05	117.82	225.29	502.16
2	1	2	328.27	241.43	572.12	1141.83
2	2	1	141.00	111.06	207.57	459.64
2	2	2	283.63	221.75	443.42	948.80
2	3	1	139.43	106.84	143.13	389.40
2	3	2	211.41	219.17	347.62	778.20
Total			**2863.59**	**2423.42**	**2584.79**	**2125.80**

The degree of freedom for each main effect is one less than the number of levels of the corresponding factor. The degree of freedom for each interaction is the product of the degrees of freedom for those factors appearing in the interaction. The degree of freedom for the three main effects are 1, 2, 1 while the degree of freedom for the two way interactions are 2 ,1, 2 and degrees of freedom for the three way interactions is 2.

Table 5.403 give complete analysis of variance on IRR of cauliflower.

Table 5.403: Complete Analysis of Variance for Effect of Row Spacings, Irrigation Depths and Irrigation systems on IRR of Cauliflower at T.C.D. Farm, WREMI, Samiala in 2005, 2006 and 2007

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	F	$F_{0.05}$ / $F_{0.01}$ from literature	Significance
Replicates	2	105260.41	52630.20	20.13	3.32/5.39	S
Main Effects						
A	1	88.07	88.07	0.03	4.17/7.56	N
B	2	28628.57	14314.29	5.47	3.32/5.39	S
C	1	243003.79	243003.79	92.94	4.17/7.56	S
Two way Interactions						
AB	2	1271.52	635.76	0.24	3.32/5.39	N
AC	1	166.98	166.98	0.06	4.17/7.56	N
BC	2	5733.07	2866.54	1.10	3.32/5.39	N
Three way Interactions						
ABC	2	2126.61	1063.30	0.41	3.32/5.39	N
Error	22	57521.05	2614.59			
Total	35	443800.07				

Obtaining the appropriate values of $F_{0.05}$ and $F_{0.01}$ from the literature, it was found that the test for replicates was significant at 0.05 and 0.01 levels. The test for factor A was not significant at both the levels. Factor B and factor C were significant at both the levels. Two factor interactions AB, AC and BC were insignificant at both the levels. Similarly, three factor interactions were not significant at both the levels.

It was concluded that the variations in the irrigation depths and irrigation systems affected the IRR of cauliflower. Other interactions did not affect the IRR.

5.3.2.3 Summer groundnut and cauliflower

Two crops, summer groundnut and cauliflower are grown in a year. IRR is calculated and analysis of variance is carried out for the year

Analysis of variance

Analysis of variance on combined yield of summer groundnut and cauliflower

Analysis of variance was determined to find out the effects of row spacings, irrigation depths and irrigation systems on yield of summer groundnut and cauliflower.

Combined yield of summer groundnut and Cauliflower are given in Table 5.404.

Factor	Level 1	Level 2	Level 3
A : Row Spacings	0.60 m	0.45 m	
B : Irrigation Depth	0.75 ETc	1.00 ETc	1.25 ETc
C : Irrigation Systems	MIS	ITK MIS	

Table 5.404: Effects of Row Spacing, Irrigation Depths and Irrigation Systems on Combined Yield of Summer Groundnut and Cauliflower at T.C.D. Farm, WREMI, Samiala in 2005, 2006 and 2007

Level of factors			Combined yield of Summer Groundnut and Cauliflower, quintal/ha			
A	**B**	**C**	2005	2006	2007	Total
1	1	1	261.38	217.47	331.74	810.59
1	1	2	262.98	218.68	373.07	854.73
1	2	1	258.87	212.20	277.15	748.23
1	2	2	246.85	215.56	251.76	714.17
1	3	1	201.19	205.71	229.79	636.70
1	3	2	211.89	208.77	298.73	719.39
2	1	1	311.73	250.94	409.53	972.19
2	1	2	315.85	252.40	502.10	1070.36
2	2	1	282.00	237.72	381.08	900.79
2	2	2	281.67	235.28	401.52	918.46
2	3	1	277.72	228.94	281.18	787.84
2	3	2	224.21	230.77	327.02	781.99
Total			**3136.33**	**2714.43**	**4064.67**	**9915.44**

The degree of freedom for each main effect is one less than the number of levels of the corresponding factor. The degree of freedom for each interaction is the product of the degrees of freedom for those factors appearing in the interaction. The degree of freedom for the three main effects are 1, 2, 1 while the degree of freedom for the two way interactions are 2 ,1, 2 and degrees of freedom for the three way interactions is 2.

Table 5.405 shows complete analysis of variance.

Table 5.405: Complete Analysis of Variance for Effect of Row Spacings, Irrigation Depths and Operation Methods on Combined Yield of Summer Groundnut and Cauliflower at T.C.D. Farm, WREMI, Samiala in 2005, 2006 and 2007.

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	F	$F_{0.05}$ & $F_{0.01}$ from literature	Significance
Replicates	2	79527.04	39763.52	30.39	3.32/5.39	S
Main Effects						
A	1	24955.73	24955.73	19.07	4.17/7.56	S
B	2	25545.68	12772.84	9.76	3.32/5.39	S
C	1	1142.09	1142.04	0.87	4.17/7.56	N
Two way Interactions						
AB	2	1322.87	661.43	0.50	3.32/5.39	N
AC	1	8.22	8.22	0.00	4.17/7.56	N
BC	2	1060.01	530.00	0.40	3.32/5.39	N
Interactions						
ABC	2	1111.21	555.60	0.42	3.32/5.39	N
Error	22	28779.09	1308.14			
Total	35	163451.99				

Obtaining the appropriate values of $F_{0.05}$ and $F_{0.01}$ from the literature, it was found that the test for replicates was significant at 0.05 and 0.01 levels. The tests for factor A and factor B were significant at both the levels, while test of factor C was insignificant at both the levels. Two factor interactions, AB, AC and BC were insignificant at both the levels. Similarly, three factor interactions were not significant at both the levels.

It was concluded that the variations in the row spacings and irrigation depths affected the combined yield of summer groundnut and cauliflower and irrigation systems did not affect the combined yield of summer groundnut and cauliflower. Other interactions did not affect the yield.

Analysis of Variance on Combined IRR of Summer Groundnut and Cauliflower

Analysis of variance was determined to find out the effects of row spacings, irrigation depths and irrigation systems on IRR of summer groundnut and cauliflower.

Factor	Level 1	Level 2	Level 3
A : Row Spacings	0.60 m	0.45 m	
B : Irrigation Depth	0.75 ETc	1.00 ETc	1.25 ETc
C : Irrigation Systems	MIS	ITK MIS	

Table 5.406shows IRR for three years for various factors.

Table 5.406: Effects of Row Spacing, Irrigation Depths and Irrigation Systems on Combined IRR of Summer Groundnut and Cauliflower at T.C.D. Farm, WREMI, Samiala in 2005, 2006 and 2007

Level of factors			Internal Rate of Return, %			
A	B	C	2005	2006	2007	Total
1	1	1	100.40	84.18	132.72	317.30
1	1	2	197.99	167.21	289.22	654.42
1	2	1	98.48	80.84	106.90	286.23
1	2	2	184.82	162.62	189.48	536.91
1	3	1	72.82	76.91	86.01	235.75
1	3	2	154.09	155.07	224.31	533.47
2	1	1	100.47	80.86	132.29	313.62
2	1	2	203.95	166.39	327.07	697.41
2	2	1	88.49	74.12	121.27	283.88
2	2	2	181.29	152.06	257.17	590.51
2	3	1	85.62	69.32	85.22	240.17
2	3	2	140.13	145.37	206.00	491.51
Total			1610.73	1417.11	1608.56	1414.95

The degree of freedom for each main effect is one less than the number of levels of the corresponding factor. The degree of freedom for each interaction is the product of the degrees of freedom for those factors appearing in the interaction. The degree of freedom for the three main effects are 1, 2, 1 while the degree of freedom for the two way interactions are 2 ,1, 2 and degrees of freedom for the three way interactions is 2. Table 5.407 shows complete analysis of variance.

Table 5.407 gives effects of row spacing, Irrigation depths and irrigation systems on combined IRR of summer groundnut and cauliflower.

Table 5.407: Complete Analysis of Variance for Effect of Row Spacings, Irrigation Depths and Irrigation Systems on Combined IRR of Summer Groundnut and Cauliflower at T.C.D. Farm, WREMI, Samiala in 2005, 2006 and 2007

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	F	$F_{0.05}$ & $F_{0.01}$ from literature	Significance
Replicates	2	24740.37	12370.18	19.41	3.32/5.39	S
Main Effects						
A	1	78.11	78.11	0.12	4.17/7.56	N
B	2	9783.69	4891.84	7.67	3.32/5.39	S
C	1	92749.76	92749.76	145.56	4.17/7.56	S
Two way Interactions						
AB	2	386.97	193.48	0.30	3.32/5.39	N
AC	1	87.81	87.81	0.13	4.17/7.56	N
BC	2	1565.65	782.82	1.22	3.32/5.39	N
Three way Interactions						
ABC	2	533.71	266.85	0.41	3.32/5.39	N
Error	22	14018.21	637.19			
Total	35	143944.31				

Obtaining the appropriate values of $F_{0.05}$ and $F_{0.01}$ from the literature, it was found that the test for replicates was significant at 0.05 and 0.01 levels. The tests for factor A were not significant at both the levels. Test for factor B and factor C were significant at both the levels. Two way interactions, AB, AC and BC were insignificant at both the levels. Similarly, three way interactions were not significant at both the levels.

It was concluded that the variations in the irrigation depths and irrigation systems affected the combined IRR of summer groundnut and cauliflower. Other interactions did not affect the IRR.

5.4 Conclusions

5.4.1 Indoor ITK MIS laboratory work

- Loss of head along the lateral were determined and used to calculate F factor.

- Regression equations were developed to determine head loss at outlets and could be utilized for design of ITK MIS.

- Head loss through polytube at each outlet could be determined using developed Regression equations.

- For ITK MIS, F factor derived by earlier researchers cannot be used as exponent of discharge to determine friction factor f is difficult to derive analytically and graphically. This is so because every outlet has polytube of different diameter and length. A micro manifold is attached to the other end of the polytube. To this 1 to 4 microtubes of different diameter and length are attached. Therefore experimental approach is adopted to determine F factor for 20 mm lateral.

- With reference to analysis of Fig. 5.229 to 5.234, in ITK MIS, F factor depends on the no.of microtubes attached to the polytube. F factor for one particular diameter of polytube increases with increase in no. of microtubes. This proves that F factor depends on discharge through outlet (i.e. microtube).

- F factors are developed for each combination of polytubes and microtubes for 20 mm lateral and are now readily available for design of ITK MIS.

- For laterals of 12 mm and 16 mm, F factor comes to more than 1.0 at first outlet due to more head loss observed along the section of the lateral upto the first outlet compared to theoretical head loss up to the first outlet using the calculated friction factor by Churchill's equation, length of the lateral upto the first outlet, observed discharge and inner diameter of the lateral. This may be due to pressure transducers with least count of 0.1 m is used.

If the pressure transducers having 0.01 m or 0.001 m least count were used, then this problem could be solved and F factor for 12 mm and 16 mm laterals could be determined. Otherwise or meanwhile only 20 mm laterals can be used for the ITK MIS.

- The length of microtube could be determined to achieve desired discharge for a given inlet pressure using the developed regression equations.

5.4.2 Field experimental work

5.4.2.1 Summer groundnut

- In MIS, maximum yield is 22.79 quintal/ha for row spacing 0.6 m and 28.34 quintal/ha for 0.45 m row spacing for 75 % of crop water requirement.

- For MIS, maximum Internal Rate of Return is 25.67 % for 0.6 m and is 30.89 % for 0.45 m spacing.

- In ITK MIS, maximum yield is 22.06 quintal/ha for 0.6 m row spacing and is 27.17 quintal/ha for 0.45 row spacing for 75 % of crop water requirement.

- For ITK Micro irrigation system, Internal Rate of Return is 54.96 % for 0.6 m spacing and 65.49 % for 0.45 m spacing.

- From the analysis of variance on yield of crop, it is concluded that the variations in the row spacings and irrigation depths affect the yield of summer groundnut but the irrigation system does not affect the yield of summer groundnut. Interactions of row spacings, irrigation depths and irrigation systems do not affect the yield.

- From the analysis of variance on IRR, it is concluded that the variations in the row spacings, irrigation depths and irrigation systems affect the IRR of summer groundnut. Interactions of row spacings, irrigation depths and irrigation systems do not affect the IRR of summer groundnut.

5.4.2.2 Cauliflower

- In MIS, maximum yield is 250.93 quintal/ha for row spacing 0.6 m and 301.93 quintal/ha for 0.45 m row spacing for 75 % of crop water requirement.

- In MIS, maximum Internal Rate of Return is 172.03 % for 0.6 m and is 167.35 % for 0.45 m spacing.

- In ITK MIS, maximum yield is 273.08 quintal/ha for 0.6 m row spacing and is 349.52 quintal/ha for 0.45 row spacing for 75 % of crop water requirement.

- For ITK MIS, Internal Rate of Return is 359.28 % for 0.6 m row spacing and 380.56 % for 0.45 m row spacing.

- From the analysis of variance on yield, it is concluded that the variations in the row spacings and irrigation depths affect the yield of cauliflower but the irrigation system do not affect the yield of cauliflower.

- From the analysis of variance on IRR, it is concluded that the variations in the irrigation depths and irrigation systems affect the IRR of cauliflower. Interactions of row spacings, irrigation depths and irrigation systems do not affect the IRR of cauliflower.

5.4.2.3 Combination of summer groundnut and cauliflower

- For MIS, maximum Internal Rate of Return is 107.24 % for 0.6 m row spacing and is 106.61 % for 0.45 m row spacing for 75 % of crop water requirement.

- For ITK MIS, maximum Internal Rate of Return is 226.27% for 0.6 m row spacing and 245.49 % for 0.45 m row spacing for 75 % of crop water requirement.

- From the analysis of variance on IRR considering summer groundnut and cauliflower it is concluded that the variations in the irrigation depths and irrigation systems affect the combined IRR of summer groundnut and cauliflower. Interactions of row spacings, irrigation depths and irrigation systems do not affect the combined IRR of summer groundnut and cauliflower.

- Thus it is concluded that from the point of view of IRR, ITK MIS gives the higher IRR and hence it is better than MIS.

- From the point of view of variance in IRR, it is concluded that variation in irrigation system i.e. MIS or ITK MIS affect the IRR. ITK MIS gives the better IRR.

5.5 Recommendations

5.5.1 Indoor ITK MIS laboratory work

ITK MIS can be designed for 20 mm lateral using F factor for various combinations of diameter and length of polytube and microtube and number of microtubes.

5.5.2 Field experimental work

ITK MIS is recommended to the farmers for summer groundnut and cauliflower as IRR is higher by 130 % compared to that of MIS for row spacing 0.45 m.

The IRR of the ITK MIS is 130 % more than that of the MIS as the cost of the ITK MIS is 40 % less than that of MIS.

Future scope of work

Determination of F factor for 12 mm, 16 mm and 25 mm diameter of laterals for ITK MIS with pressure transducers having least count of 0.01 or 0.001 m.

Determination of F factor for various diameter of manifold, submain and main for ITK MIS.

Head loss through various length and diameter of micromanifold attached to the polytube in ITK MIS.

Design of ITK MIS for various crops like cotton, banana, orchard crops and its economic analysis.