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Optimizations of Design of Different Types of Drip Irrigation Systems for Savings of Water and Energy for Various Commercial Crops

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Abstract: **Efforts have been exercised to design the optimized and viable systems to deliver a predefined amount of water at the root zones of the plant at regular intervals so that the plants do not suffer from stress or strain of less and over watering. Computational analysis have been made for drip irrigation systems of multi loop (closed end type) and multi lateral (open end type) piping network with provisions of pressure regulating devices . Various performance parameters have been compared for both types of networking with respect to the types of crops and it's water requirement, land areas and it's shape and orientation, soil types, area of effective root zones, sizes of lateral, sub-main, main and emitters, pressure variations and other associated parameters. The lands of new alluvial agro-climatic zone with sandy loam type soil and areas of 5 acres, and 3acres and fruit crops like coconut and Guava have been considered for analysis. Optimizations have been made to develop the efficient piping network with higher values of emission uniformities, minimum wastage of water, minimum consumption of power, higher pressure balancing and better performance parameters and hence to achieve the efficient irrigation systems with the maximum savings of these precious utilities.**

With the sizes of various key components,[For coconut/guava fields: Main (Polyvinyl chloride): 40mm/75mm (dia.); Sub main (Polyvinyl chloride): 30mm/63mm(dia.); Lateral (Polyethylene): 15mm/20mm (dia.); Emitters: (6 lph for both coconut and guava and 3 emitters per plant)], the following observations have been made:

i) Savings of power ranges from 52% to 67 % for coconut and 52 % to 63 % for guava may be achieved in multi-loop type piping network as compared to the similar open type piping network depending upon the various associated parameters as afore-specified.

ii)Emission Uniformities in the range from 93% to 98 % in both types of piping network may be achieved through the provisions of pressure regulating devices.

iii) Pressure reduction of much higher ranges are required through regulating devices between main and sub-main in the open type configuration to achieve higher values of Emission Uniformities as compared to the similar type of closed type configurations. This results higher amount of energy savings in multi-loop type configuration of piping network.

Therefore, better performances in terms of power consumptions, emission uniformities, savings of energy and water, pressure balancing and other associated parameters can be achieved in the multi-loop type piping systems as compared to the similar type of multilateral piping systems.

Keywords: Drip irrigation, Optimization, Power consumption, Emission Uniformities, Pressure balancing; Piping Network, Efficiency, Meter Water Column, Water consumption, liters per hour. High-density polyethylene, low-density polyethylene and linear low-density polyethylene.

1. INTRODUCTION

As the world population increases from the current level of six billion to nine billion by 2050 thus requiring a 60% increase in global food production. Utilizable fresh water resources present in the form of ground and fresh water, lakes and stable run-off form a minute fraction (0.003%) of the total water resources (1400 million Km3) on the earth and the rest is in the form of sea water, ice caps in polar regions, inaccessible ground water and run off etc. Therefore, with the available water, productivity of agricultural foods along with qualities are to be increased through optimum utilization of available water and more and more lands are to be brought under irrigation. The irrigated area under horticultural crops has been increased from less than 6.0 m. ha in 1990-91 to about 8.14 m. ha by 2000 A.D in India. The irrigated area consists of about 36 per cent of the net sown area. Presently, the agricultural sector accounts for about 83 per cent of all water uses. The remaining uses include 5, 3, 6 and 3 per cent respectively, by

domestic, industrial and energy sectors and other consumers. Thus a large area will continue to be under rain fed conditions. The National Committee on Plasticulture Applications in Horticulture (NCPAH), Ministry of Agriculture, Government of India has estimated presently a total of 27 million hectares area in the country that has the potential of drip irrigation application.

Drip irrigation is an most potential methods when installed for irrigating suitable crops under challenging soil & water supply conditions and could bring additional area under cultivation of horticultural crops with same quantity of available water. Besides water and electricity saving, higher water and nutrients use efficiencies reduction in cost of cultivation and improvement in productivity are the two other advantages of drip method of irrigation. In spite of proven benefits and attractive subsidies, it's adoptions has remained low due to higher installation costs, power consumptions, management intensiveness, inadequate extension and infrastructural facilities. As regards Benefit-Cost (B-C) ratio, it is estimated that investment in drip method of irrigation is economically viable, even if it is estimated without taking into account subsidy given to farmers. The B-C ratio estimated excluding water saving varies from 1.31 to 13.35 depending upon the types of crops and other geo-climatic conditions. The B-C ratio increases significantly further, when it is estimated after including water saving. Nutrients Use Efficiency could reach as high as 90 per cent besides achieving > 95 per cent application efficiency. Therefore, the amount of fertilizer lost through leaching could be as low as 10% in drip fertigation as compared to 50% in the traditional one.

Although drip irrigation is an acceptable technology by the Indians farmers, its rate of adoption is limited in annual crops due to involvement of initial high capital cost. Nevertheless, the area under drip irrigation has increased manifolds from 1,500 ha (1989) to nearly 2 mha (2010,) which is extremely miniscule when compared to the potential of 69 m.ha. Drip irrigation is adopted extensively in areas of acute water scarcity and especially for crops and trees such as coconuts, containerized landscape trees, grapes, bananas, ber, eggplant, citrus, strawberries, guava, sugarcane, cotton, maize, and tomatoes.

2. COCONUT, (*COCONUCIFERA*)

It is a monocotyledon belonging to the order *Palmae*. Coconuts have a very dense, fibrous root system that is mostly within 1.5 m of the soil surface. Coconut water is a very refreshing drink to beat tropical summer thirst. The juice is packed with simple sugar, electrolytes, minerals, and bioactive compounds such as cytokinin, and enzymes such as acid phosphatase, catalase, dehydrogenase, peroxidase, polymerases, etc. Altogether, these enzymes aid in digestion and metabolism. The kernel is an excellent source of minerals such as copper, calcium, iron, manganese, magnesium, and zinc. It is also a very good source of B-complex vitamins such as folates, riboflavin, niacin, thiamin, and pyridoxine. Coconut may provide a wide range of health benefits like it helps to kill viruses that cause influenza, herpes, measles, hepatitis C, SARS, AIDS, and other illnesses. It also helps to kill bacteria that cause ulcers, throat infections, urinary tract infections, gum disease and cavities, pneumonia, and gonorrhea, and other diseases**.** A survey made by Coconut Development Board reveals that in India total 21892 million nuts (14006.5 MT) production was observed from the area of cultivation of about 2039.1 thousand hectares during the year 2011-12.

3. GUAVA (PSIDIUM GUAJAVA)

It is one of the important commercial fruits in India. It is the fourth most important fruit after mango, banana and citrus. The fruit is a good source of vitamin C, pectin, calcium and phosphorus. The fruit is used for the preparation of processed products like jams, jellies and nectar. Guava jelly puree is very popular for its attractive purplish-red colour, pleasant taste and aroma. Guava is used in the treatment of diarrhea, dysentery, constipation, coughs, olds, various skin problems, high blood pressure, weight loss, scurvy, etc. Leaves of guava are used for curing diarrhoea and also for dyeing and tanning. The total area in India under guava cultivation during 2010-11 was 204.8 thousand hectares and the crop amounted to 2462.3 metric tones as compared to 154.6 thousand hectares area and crop amounted to 1715.5 thousand metric tons during the year 2000-01.

4. OBJECTIVES

Efforts have been exercised to develop the efficient piping network with minimum pipe diameter and length for different types of high values horticultural crops like Coconut and Guava to have the higher emission uniformities, minimum wastage of water, minimum consumption of power, higher pressure balancing, minimum time of irrigation, minimum pressure head, optimum water supply at the root zone and other associated parameters and to achieve the efficient drip irrigation systems with maximum savings of these precious consumables.

While designing the drip irrigation system, highest water required for the plant throughout its lifecycle is considered for calculation of water requirement. While calculating peak water requirement, peak rate of evapo-transpiration is taken into consideration. Selection of drippers should be based on water requirement, soil type, water availability, electricity availability etc to emit enough water to fulfill water requirement within predefined time. Totally optimized, efficient and long-life system ensures saving in water, early maturity and a bountiful harvest, season after season, years after years. Apart from all these, savings in labour and fertilizer costs can also be made.

5. MATERIALS AND METHODS

The land of new alluvial agro-climatic zone with sandy loam type soil and crop field areas of 5 acres and 3 acres and fruit crops having high commercial values like coconut and guava have been considered separately for development of the efficient type of piping network through computational analysis.

The following two types of piping network with the provisions of pressure regulating devices have been developed.

i) Multi loop type where both ends of the lateral are connected to the sub mains and a closed network have been formed through main pipe.

ii) Open type (Multilateral) where one end is connected with the sub-main and other end is blocked with end cap. Sub mains are connected with a common main pipe. Pressure regulations have been provided between main and sub main wherever it is required to achieve higher emission uniformities.

The various **design parameters** have been furnished in the Table-1 and Table –2.

Table 1. Various design parameters considered for different types of piping network for drip irrigation systems for different areas of crop-field (Coconut)

Sl. No.	Parameters	5 Acres		3 Acres	
		Loop	Open	Loop	Open
(i)	Total nos. of plants	348	348	198	198
(ii)	Nos. of rows of plants	58	58	33	33
(iii)	No of plant in each row	06	06	06	06
(iv)	Spacing of plant (m x m)	8 x 8	8 x 8	8 x 8	8 x 8
(v)	Nos. of laterals	58	58	33	33
(vi)	Nos. of rows covered by each lateral	01	01	01	01
vii)	Total area (LXW)of the crop field (m x m)= (sq-m)	460X44 =20240	460X44 =20240	264X46 =12144	264X46 =12144
viii)	Distance between two adjacent lateral (m)	08	08	08	08
ix)	Nos. of plant covered by each lateral	06	06	06	06
x)	Distance between two adjacent plant along each row (m	08	08	08	08
xi)	Total length of sub main (m)	456 x 2	456 x 1	256 x 2	256 x 1
xii)	Length of main(m) (m)	362x2	341x1	194x2	173x1
xiii)	Length of each lateral(m)	42	42	42	42
xiv)	ID(mainl/sub main/lateral)(mm)	40/30/15	40/30/15	40/30/15	40/30/15
xv)	Pressure rating of main/sub main(Kg/cm²g)	4-6	4-6	4-6	4-6
xvi)	Thickness of lateral (mm)	1-3	1-3	1-3	1-3
xvii)	Peak water requirement in each plant(Lit/day)	50	50	50	50
xviii)	Effective Root Zone; Rad(m); (Area (Sq.m))	3 28.26	3 28.26	3 28.26	3 28.26
xix)	Nos.of emitters/plant	03	03	03	03
xx)	Type of emitters	Short orifice	Short orifice	Short orifice	Short orifice
xxi)	Recommended discharge (lph) & base press(MWC)	06 02	06 02	06 02	06 02
xxii)	Duration of irrigation/day	2hrs 47min	2hrs 47min	2hrs 47min	2hrs 47min

Table 2. Various design parameters considered for different types of piping network for drip irrigation systems for different areas of crop-field (Guava)

Sl. No.	Parameters	5 Acres		3 Acres	
		Loop	Open	Loop	Open
(i)	Total nos. of plants	828	828	504	504
(ii)	Nos. of rows of plants	92	92	56	56
(iii)	No of plant in each row	09	09	09	09
(iv)	Spacing of plant (m x m)	5x5	5x5	5X5	5X5
(v)	Nos. of laterals	92	92	56	56
(vi)	Nos. of rows covered by each lateral	01	01	01	01
vii)	Total area (LXW)of the crop field (m x m)= (sq-m)	460X44 =20240	460X44 =20240	276X44 =12144	276X44 =12144
viii)	Distance between two adjacent lateral (m)	05	05	05	05
ix)	Nos. of plant covered by each lateral	09	09	09	09
x)	Distance between two adjacent plant along each row (m)	05	05	05	05
xi)	Total length of sub main (m)	440 x 2	440 x 1	270 x 2	270 x 1
xii	Length of main(m)	437x2	415x1	129x2	104X 1
xiii)	Length of each lateral (m)	40	40	40	40
xiv)	ID(main/sub main/lateral) (mm)	75/63/20	75/63/20	75/63/20	75/63/20
xv)	Pressure rating of main/sub main (Kg/cm²g)	4-6	4-6	4-6	4-6
xvi)	Thickness of lateral (mm)	1-3	1-3	1-3	1-3
xvii	Peak water requirement in each plant (Lit/day)	85	85	85	85
xviii	Effective Root Zone; Rad (m); (Area (Sq.m))	1.5 7.10	1.5 7.10	1.5 7.10	1.5 7.10
xix)	Nos.of emitters/plant	03	03	03	03
xx)	Type of emitters	Short orifice	Short orifice	Short orifice	Short orifice
xxi)	Recommended discharge (lph) & base press(MWC)	06 02	06 02	06 02	06 02
xxii)	Duration of irrigation/day	4hrs 43min	4hrs 43min	4hrs 43min	4hrs 43min

Parameters Common for Piping Network for Both Types of Crop Fields (Coconut & Mango)

a) Materials of construction of

i) Emitters: Polyvinyl Chloride (PVC)/ Polyethylene (PE)/ LLDPE
ii) Pipes for Lateral (ID20/15): Extruded LDPE and LLDPE Pipes
iii) Pipes for main/ sub main (ID 40/30/63/75): Extruded HDPE pipes/rigid PVC pipes
iv) End caps, fittings and accessories: Polypropylene/ Moulded type
v) Pressure regulating devices and it's locations: Pressure regulation is made with different end conditions and located between main and sub main.
vi) Valves: Non -return valve (NRV), Ball valves, Air release valve (ARV), flush valve
vii) Filtration and its location: Mechanical Filtration including basins, screens. Centrifugal and separation. of the aforementioned types separately within the crop field areas.

Hazen-William's formula has been used for finding out the pressure loss against the flow through the piping network.

Pressure head and water supply rate (capacity), power required at the entry to the crop field along with other associated performance parameters have been computed and compared.

Computational analysis and simulation have been made for the piping network

6. RESULTS AND DISCUSSIONS

Comparison of various performance parameters of the drip irrigation systems of aforesaid types of different areas of crop field and fruits have been made and furnished in the following tables.

Table 3. Comparison of required flow rate of water (Liters/hr) in the main pipe at the entry to the crop field between Multi loop (Closed end) and Multilateral (Open) type drip irrigation systems

Fruits	5 Acres			3 Acres		
	Loop	Open	Savings	Loop	Open	Savings
Coconut	6439	6913	474	3608	3758	149
Guava	15304	*17388*	2084	9636	10432	796

Table 4. Comparison of water requirement (Liters/day) and it's savings

Fruits	5 Acres			3 Acres		
	Loop	Open	Savings	Loop	Open	Savings
Coconut	17900	19216	1316	10032	10448	415
Guava	72183	82013	9830	45385	49135	3750

Table 5. Comparison of Pressure head (MWC) required at the entry to the crop field

Fruits	5 Acres			3 Acres		
	Loop	Open	Savings	Loop	Open	Savings
Coconut	10.48	30.65	20.12	3.67	7.417	3.75
Guava	5.241	12.72	4.589	4.05	7.85	3.80

Table 6.Comparison of power consumption (Watt) required at the entry to the crop field

Fruits	5 Acres			3 Acres		
	Loop	Open	Savings (%)	Loop	Open	Savings (%)
Coconut	183.88	576	390 (67.65%)	36	75	39 (52%)
Guava	218	602	384 (63.78%)	106	223	117 (52.46%)

Table 7. Comparison of energy consumption (KJ/day) required at the entry to the crop field

Fruits	5 Acres			3 Acres		
	Loop	Open	Savings	Loop	Open	Savings
Coconut	1834	5772	3938	361	752	391
Guava	3865	7912	4047	1797	3781	1984

Table 8. Comparison of Emission Uniformities (%)

Fruits	5 Acres		3 Acres	
	Loop	Open	Loop	Open
Coconut	97.40	90.15	98.46	95.88
Guava	96.51	92.62	98.30	93.10

Table 9. Comparison of pressure regulations (MWC X MWC) across main and sub-main of Multi loop (Closed end) and Multilateral (Open) type drip irrigation systems.

Fruits	5 Acres		3 Acres	
	Loop	Open	Loop	Open
Coconut	5.03X2.37	14.37X 3.41	2.34X2.21	3.34X2.86
Guava	4.08X2.11	8.56 X 3.89	2.63X2.27	5.17X3.12

From the afore furnished results, the following observations have been made:

i) Savings of power ranges from 52% to 67% for coconut and 52% to 63% for Guava may be achieved in multi loop type piping network as compared to the similar open type piping network depending upon the various associated parameters as afore specified. Savings increases as the area of crop field increases.

ii) Savings of water and energy consumption per day also appeared in appreciable amount and hence cost of irrigation in overall also get reduced and optimized.

iii) Emission Uniformities in the range from 93% to 98% in both types of piping network may be achieved through the provisions of pressure regulating devices.

iv) Pressure reduction of much lower ranges are required through regulating devices between the main and sub main in the multi loop type piping network to achieve higher values of Emission Uniformities as compared to the open type configuration. This results higher amount of energy savings in multi loop type configuration of piping network.

v) Pressure variation along the sub main and also along the individual lateral are in much lower range in multi loop type piping network as compared to the similar open type piping network resulting the achievement of better pressure balancing throughout the network within the crop field.

7. CONCLUSIONS

Better performances in terms of power consumptions, emission uniformities, savings of power and water, lower ranges in pressure regulations, pressure balancing and other associated parameters can be achieved in the multi loop type piping systems as compared to the similar type of multilateral piping systems. As the Crop field areas increases, savings of power and water becomes more and significant.

REFERENCES

[1] Drip and Micro Irrigation Design and Management for Trees, Vines, and Field Crops, 3rd Edition, by Charles M. Burt and Stuart W. Styles, published by the Irrigation Training and Research Center, 2007.

[2] Sulochanamma BN, Reddy TY, Reddy GS (2005). Effect of basin and drip irrigation on growth, yield and water use efficiency in pomegranate cv. Ganesh. Acta ort. 96:277-279.

[3] Keller, Jack and Ron Bliesner. 2000. Sprinkler and Trickle Irrigation. ISBN: 1-930665-19-9. Blackburn Press, Caldwell, New Jersey.

[4] Camp, C.R.1998. Sub-surface drip irrigation: a review . J. Transaction of the ASAE.41(5):1353-1367.

[5] Doorenbas, J. and Pruit, W.O.1997. Guidelines for predicting crop water requirements. Irrigation and drainage paper .24. Food and Agriculture Organization of the United Nations, Rome.pp.35-66.

[6] Proceedings of Micro Irrigation Congress 1995, Orlando, FL, USA Narayanmurti, A.1997. Economics viability of drip irrigation: An empirical analysis from Maharashtra. J. Agricultural Economics, 52(4) : 729-739.

[7] Nakayama, F. S. and Bucks, D. A. 1986. Irrigation Scheduling in trickle irrigation for crop production, Elsevier, Netherlands. p. 380.

[8] Pook, M.J.1993. Progress of drip irrigation in India, Souvenir, National Conference on plastics in Agriculture held at Chandigarh. 19-20 May, 1993.

[9] Reddy, K.Y. Rao, D.A. Satyaprasad, A. and Madhawa, M.1999. Evaluation of friction factor for trickle lateral pipes. J. Andhra Agric. 46(1&20): 87-92.