Evaluation of Girdle Sprinkler Irrigation System for Coconut in Intermediate and Dry Zone of Sri Lanka

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ABSTRACT

Irrigation has become an essential and important practice for coconut cultivation especially in Intermediate and Dry zones of Sri Lanka. Even though several methods have been recommended, none of those methods have been successfully practiced yet. The girdle sprinkler system is a new approach to overcome difficulties occurred in this sector. The objective of this study was to develop a suitable irrigation system for small scale coconut lands and to assess the best model through the study of field uniformity. The water distribution uniformity is the key parameter which was used to evaluate the system.

The girdle sprinkler irrigation system was installed in 0.4 hectare (64 palms) block as half acre was installed with 16 mm conduit pipe laterals and other half acre was installed with 20 mm PVC pipe laterals. Several modifications such as leveling of girdle sprinklers, looping of laterals, testing with different pressure levels, shifting sub-main line to the middle of the field, testing with same girdle sprinkler were carried out in order to achieve the maximum distribution uniformity. Flow rates and pressure were measured to calculate the uniformity. A comparison was carried out with drip irrigation system to evaluate the system.

The girdle sprinkler system which comprise with 1 $kgcm^{-2}$ inlet pressure with sub-mainline in middle modification having 20 mm PVC laterals has showed 94% distribution uniformity and the similar system with 16mm conduit laterals showed 91% of distribution uniformity which shows an excellent distribution uniformity. Therefore this irrigation system is a viable method for small scale coconut cultivation. This method requires very less amount of technical support to install and maintain the system.

Key words: *Flow rate, girdle sprinkler, irrigation, uniformity*

INTRODUCTION

Coconut is one of the major plantation crops in Sri Lanka, covering about 395,000 hectare (Central Bank of Sri Lanka Annual Report, 2005) and is grown in different soil types having varying moisture regimes (Somasiri *et al.*, 1994). The potential extent for coconut cultivation is 687,194 ha and spreading to different areas in coconut triangle and to down south of Sri Lanka (Tennakoon, 2005). Coconut is the most widespread plantation crop in Sri Lanka occupying about 25% of national agricultural lands (Perera, 1990). From the total extent of coconut lands 29% is situated in the Dry zone while 51% and 20% are distributed in the Intermediate and Wet zones respectively (Tennakoon, 2005). In Sri Lanka majority of the coconut lands are situated in coastal areas (coastal plane) and river basins (alluvial plane). The surface layer of most soils in coastal planes and alluvial planes are sandy in nature. The alluvial soils occurs in the mantled plane is also sandy up to 60cm depth (Somasiri *et al.*, 1994).

Coconut palm exhibits continuous concurrent vegetative and reproductive phases and its productivity is substantially influenced by environmental variables. Soil moisture has been identified as a major factor with significant influence on monthly variation of coconut yield, particularly in areas where are subjected to long dry period or where rainfall is low or poorly distributed (Somasiri *et al.*; Vidhana Arachchi, 1998a). Moisture stress is known to retard the growth of young palms, delay the initiation of flowering, increase the button nut shedding and immature nut fall and reduce the number and size of the nuts in coconut palms (Abeywardena, 1971). It also directly trigger to all physiological functions of the palm such as CO_2 intake (Taiz and Zeiger, 1991).

Although coconut is presently grown throughout all Agro-ecological Regions of Sri Lanka, only few of these environments are suitable for coconut in all aspects. Others show one or more adverse effects on its production particularly due to unfavorable soil characteristics and weather conditions (Somasiri *et al.*, 1994; Vidhana Archchi, 1998a). The crop water requirement for optimum growth is location specific and varies with climate, soil, variety/hybrid and the system of irrigation. In Thamilnadu the general irrigation recommendation is 100 liters/ palm/ day with drip irrigation (Anone; 1999) and it is 32 liters/palm/day in west coast in Ivory Coast (Nampoothiri and Singh, 2000). The general recommendation in Sri Lanka is 40 – 60 liters/palm/ day depending on the soil type (Vidhana Archchi, 1998b). Coconut palm could absorb 28 – 46 liters of water in a dry day. The estimated transpiration rate is 90 – 100 liters per palm in a dry day in the dry period (Mohandas *et al.*, 1989).

Irrigation has a greater influence on coconut yield. An experiment conducted by Coconut Research Institute revealed that there is a 49% yield increase compared to none irrigated coconut land, when coconut land is irrigated with 40 liters/palm/day at six days intervals with 250g of adult palm mixture (APM) plus 83g of dolomite at monthly intervals in the intermediate zone (Tennakoon *et al.*, 2005). Even with irrigation along shows 37% yield increase compared to none irrigated coconut land (Tennakoon, 2006). Split application of fertilizer is possible with an irrigation system which is known as fertigation. In order to fulfill the above irrigation requirement, several irrigation methods have been practiced by the growers. Drip irrigation, sprinkler irrigation, hose irrigation are some of improved methods and drip irrigation is the mostly practiced and easily available improved method in the market for coconut. However many of the above systems have shown various difficulties when used in the field. A diagnostic survey on agronomical practices on coconut revealed that the inefficiency of present irrigation systems and suggested more efficient method to be identified (Peiris *et al.*, 2006).

Irrigation uniformity is an important technical factor in any irrigation system. Irrigation uniformity refers to how the water is distributed uniformly in the irrigated area in a given time or that the depth of water application throughout the entire irrigated area is about the same (Dorota *et al.*, 2005). The degree of uniformity however, can be highly variable depending upon irrigation system and management.

The girdle sprinkler irrigation system is a new concept which tries to solve some problems prevailing in present irrigation systems. The primary objective of this study is to design and evaluate a girdle sprinkler irrigation system for coconut small holders in Sri Lanka.

MATERIALS AND METHODS

The experiment was conducted at Rathmalagara estate, Madampe by the Soils and Plant Nutrition Division, Coconut Research Institute of Sri Lanka (CRISL). The experimental location has shallow sandy clay loam soils belongs to *Andigama* soil series (Red Yellow Podsolic) which belong to the land suitability class S_4 based on the land suitability classification introduced by CRISL. 0.4 hectare square shape block of experimental plot was selected including 64 palms having 8m x 8m spacing. The slope of the selected site is 2.5%.

Two materials were tested for laterals as 20 mm PVC pipes and 16 mm conduit pipes. Four laterals were installed as two laterals for each material. Each lateral was installed in the middle of two coconut rows. Sixteen delivery tubes (sub laterals) were connected at either side and along the lateral to deliver water to coconut palms. Girdle sprinklers were connected to each delivery line and all the system was buried under one foot except girdle sprinklers. Girdle sprinklers were made using 4mm low density poly ethylene (LDPE) tubes. First the tube was circulated and tightened around the palm and then eight orifices having 1mm diameter were drilled with 20 – 30° angle from the trunk keeping equal distance between orifices. All laterals were connected to 1 inch sub main line and it was connected to 2 inches main line. A screen filter made by using 0.5 mm stainless steel wire mesh was also installed at the main line (Fig. 1 and 2).

Finally the system was operated and initial measurements were taken as flow rate and pressure at each girdle sprinkler by using a water meter and a pressure gauge. The system was

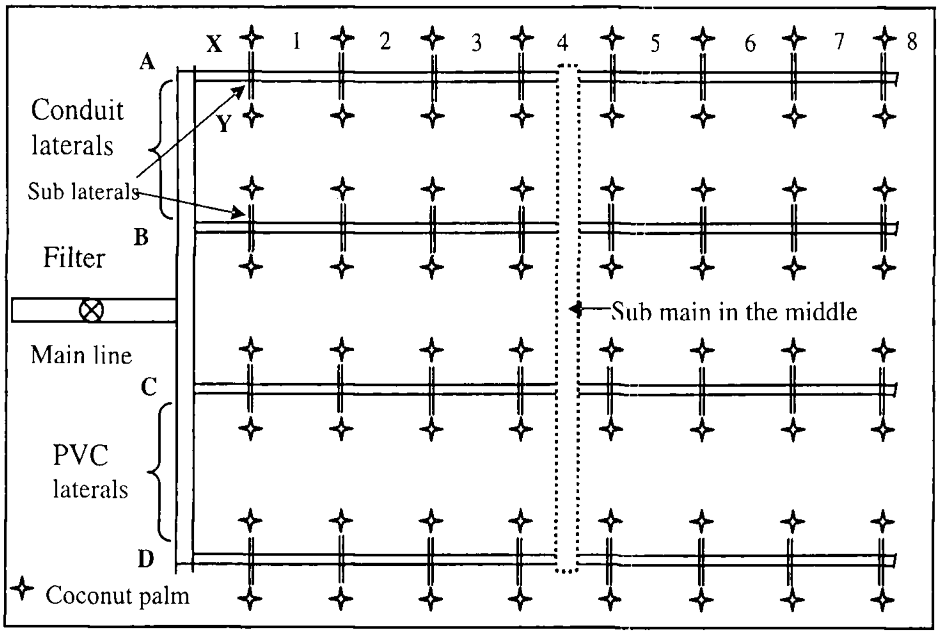

Fig. 1. *Field layout of the initial girdle sprinkler irrigation system*

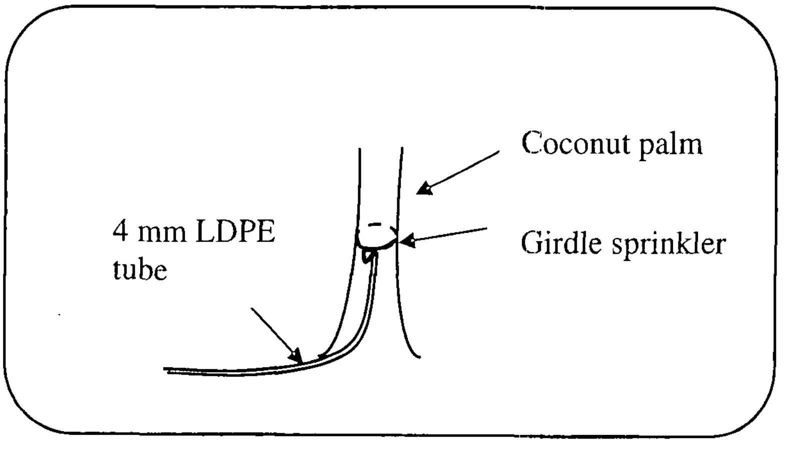

Fig. 2. *Schematic diagram of a girdle sprinkler at the coconut palm*

operated under two different pressure levels and series of modifications have been carried out as leveling of girdle sprinklers to one contour level, looping of same laterals together, shifting the sub main line to the middle of the field and measuring all points with one unique girdle in order to minimize errors due to manufacturing defects of girdle sprinklers. Flow rate and pressure were measured after each modification. Finally the system was compared with existing drip irrigation system and uniformity was calculated using distribution uniformity (DU) equation developed by Peacock *at el.*, (1998). [DU = (average low quarter flow rate / overall average flow rate) x 100%)]

RESULTS AND DISCUSSION

Pressure changes analysis

Initial pressure at each girdle sprinkler point is shown in Fig. 3. Pressure reduction is higher in conduit laterals than PVC laterals as from 1.6 kg cm^{-2} to 0.95 kg cm^{-2} and from 1.65 kg cm^{-2} to 1.35 kg cm^{-2} respectively. The operating pressure of the system is 1.75 kg cm^{-2}

The initial pressure is highly variable before modifications along the lateral in both conduit and PVC laterals. However in a particular point of a lateral, two girdle sprinklers those were connected to that particular point through sub laterals show almost equal pressure values.

Pressure variation under each modification

Pressure variation after leveling of girdle sprinklers and looping of similar laterals are shown in Fig. 4. Girdles sprinklers at the beginning of each lateral show the highest pressure values in each lateral and decrease along the lateral towards the end. This is basically due to the friction loss inside the tubing system. Initially the rate of the pressure loss is high and then the rate also decreases towards the end of the lateral. Since there is a high pressure at the beginning of the lateral the velocity of water is also high. When the velocity is high it increases the friction loss. Therefore the rate of reduction of pressure is also high at the beginning of the lateral. Similarly towards the end of the lateral the velocity of water is low due to low pressure. Therefore it reduces the friction loss too and the rate of reduction of pressure is also less.

The highest pressure for girdle sprinklers with conduit laterals is 1.75 $kgcm^{-2}$ and the lowest is 0.95 $kgcm^{-2}$. Leveling of girdle sprinklers eliminates the variation of pressure due to the slope in the field. It conserves the pressure in the system. Pressure reduction was further reduced by looping of ends of similar laterals together. The highest pressure observed at girdle sprinklers at PVC laterals was 1.75 $kgcm^{-2}$ and the lowest pressures is 1.35 $kgcm^{-2}$.

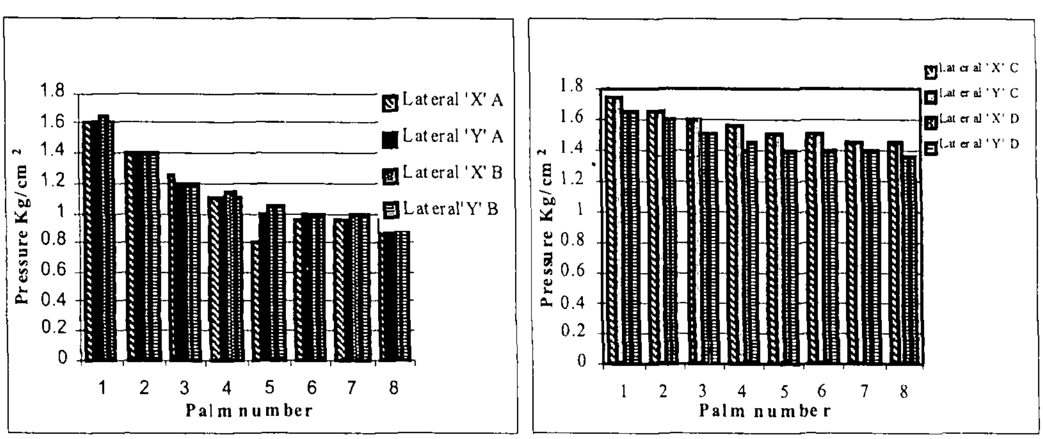

Fig. 3. *The pressure variation at girdle sprinklers in 16 mm conduit (A and B) and 20mm PVC (C and D) laterals.*

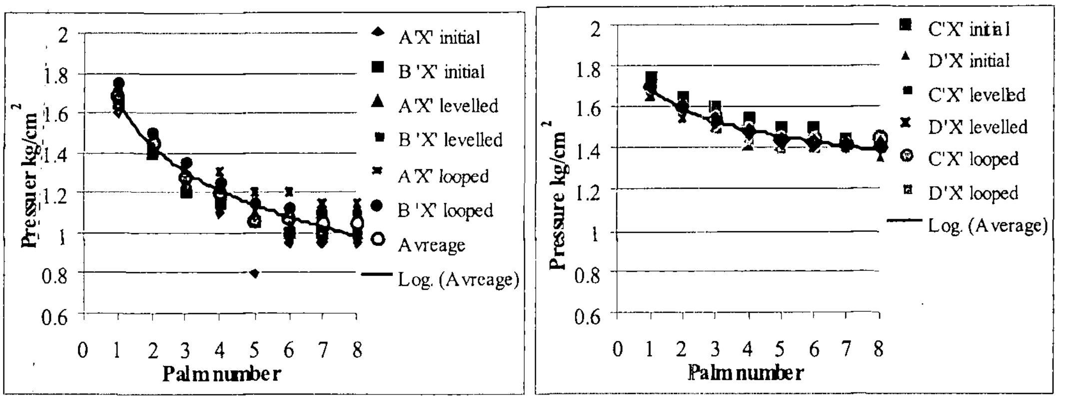

Fig. 4. *Pressure changes along the conduit laterals (A'X', B'X') and PVC laterals (C'X', D'X') under higher pressure*

According to the observed results 20 mm PVC laterals show better results than conduits. Since PVC has higher diameter than conduits it has less friction loss and due to that the pressure reduction is also less. Further, for conduits number of fittings and connecters used are higher than PVC. This also affects to reduce the pressure in conduits. However 20 mm PVC laterals are better than conduit lateral for this type of irrigation system.

Pressure change under lower operating pressure

When the girdle sprinkler system is operated under higher pressure it creates mist and water get lost by wind. On the other hand if the water application rate creates a surface runoff, flow rate should be reduced. Therefore, the system was operated under lower pressure as 1 kgcm^{-2} and the results are shown in Fig. 5.

Pressure reduction was reduced as from 1 kg cm^{-2} to 0.7 kg cm^{-2} at girdle sprinklers in conduit laterals and from 1 kg cm^{-2} to 0.8 kg cm^{-2} at girdle sprinklers in PVC laterals. The percentages of pressure changes in conduit laterals and PVC laterals are 30% and 20% respectively. This result indicates that the operation of girdle sprinklers under lower pressure increases the accuracy of water application.

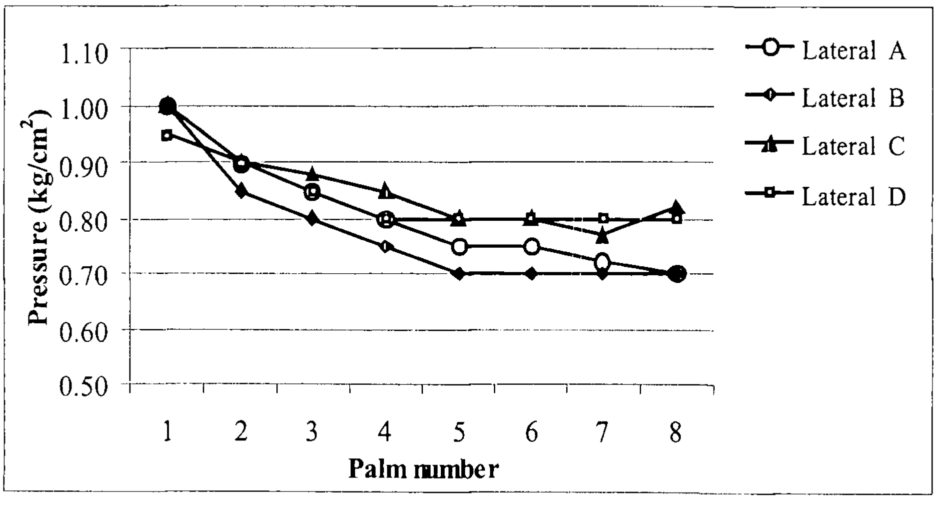

Fig. 5. *Pressure change along the laterals under lower pressure A, B – Conduit laterals C, D – PVC laterals*

Pressure change analysis with sub mainline in the middle of the system

When the sub mainline is shifted to the middle of the irrigated field the length of all laterals are reduced by half of the initial length. The system was operated under 0.99 kgcm^{-2} mainline pressure. Results are shown in Fig. 6.

from 0.99 kg cm^{-2} to 0.89 kg cm^{-2} which show just 10.1% reduction. Girdle sprinkles at PVC laterals shows pressure reduction from 0.95 kg cm^{-2} to 0.90 kg cm^{-2} which is just 5% reduction. Still PVC laterals give better results than conduits laterals.

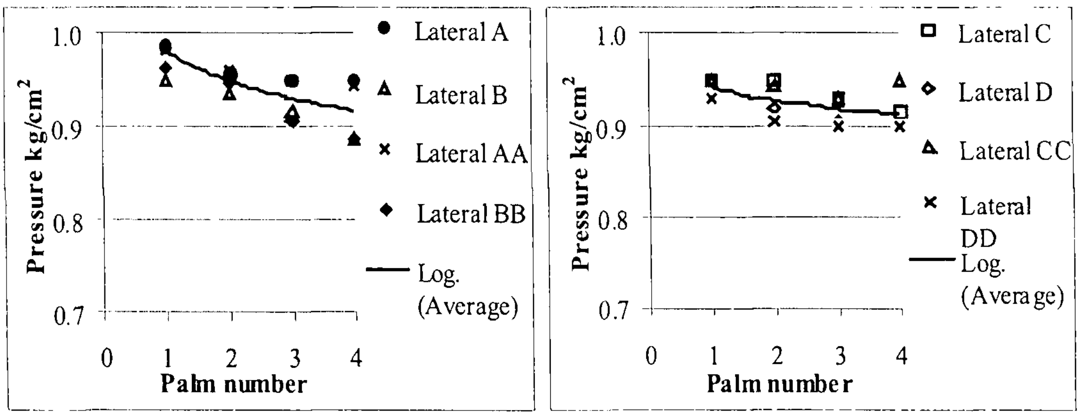

Fig. 6. *Pressure change along the 16mm conduit laterals and 20 mm PVC laterals under lower pressure*

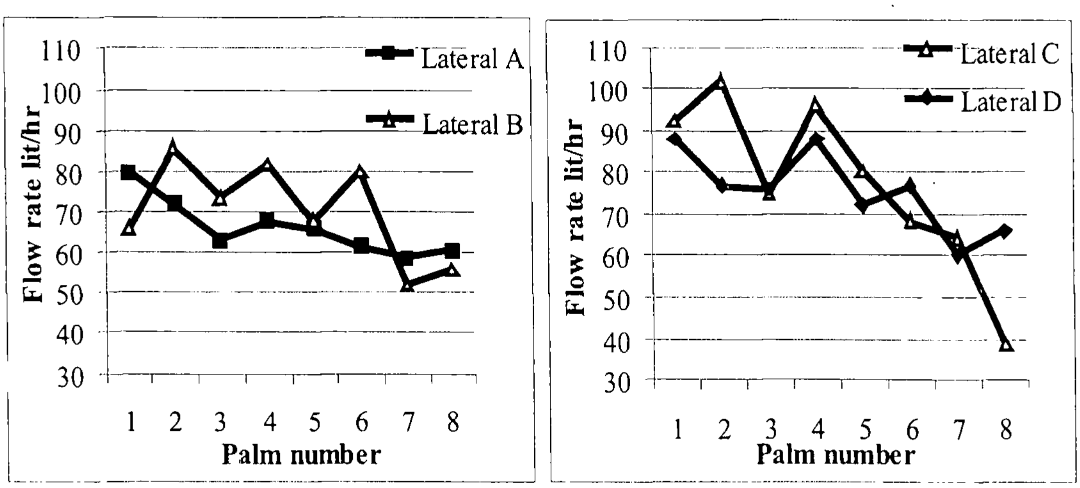

Fig.7. *Flow rate variation along the 16mm conduit laterals (a) and 20mm PVC laterals (b) at the initial modification*

The pressure reduction was further reduced towards the end in both lateral types. This system increases the uniformity of water application. Further the maintenance of the system would be much easier with laterals with short length. Pressure changes in girdle sprinklers at conduit laterals is

Flow rate changes analysis

Flow rate is the most important parameter for any type of micro irrigation system. It determines the application uniformity of system and the total time required for one irrigation cycle too. The flow rate should be related with the soil characteristics in order to minimize water losses through surface and subsurface runoff and evaporation. Initial flow rates at each girdle sprinklers in the whole system shows very high variation as shown in Fig. 7.

Girdle sprinklers with 16mm conduit laterals show 68.23 liters/hour average flow rate varying between 79.69 liters/hour and 51.80 liters/hour when operated under 1.65 kg/cm^2 mainline pressure. Similarly girdle sprinklers at 20mm PVC laterals show 76.81 liters/hour averaged flow rate. It also varied between 101.41 liters/hour and 39 liters/hour this variation is basically due to the pressure losses along the laterals, undulating pattern of the land prior to leveling of girdle sprinklers. Further the variation of diameters in orifices of girdle sprinklers also increases the flow rate variation.

Leveling of girdle sprinklers and looping of similar laterals together show a significant reduction of flow rate variation. It increases the application uniformity further.

Flow rate changes after leveling of girdle sprinklers and looping of laterals are shown in Fig. 8. Mean flow rate at each lateral system was increased due to the conservation of pressure inside the system. Leveling of girdle sprinklers for a particular height solves the slope effect to the system.

Girdle sprinkler system operated under 1.6 kg cm^{-2} mainline pressure causes mist formation and it creates fairly higher variation of flow rates between girdle sprinklers. It also makes surface runoff and subsurface runoff when the flow rate is higher than that of infiltration rate. Therefore, the maximum application flow rate depends on the infiltration rate of the soil.

In order to prevent above losses the system was operated under lower pressure as 1 kg cm^{-2} and results are shown in Fig. 9.

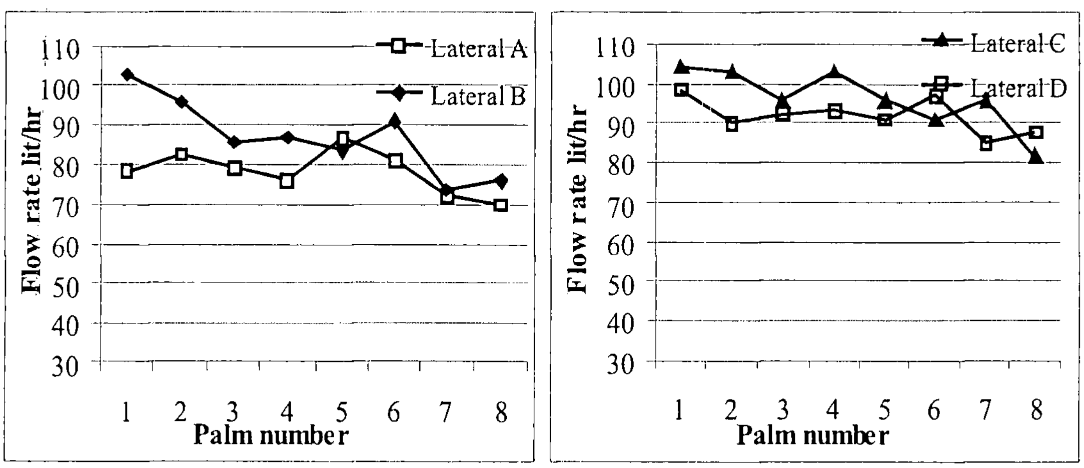

Fig.8. *Flow rate variation along the 16mm conduit laterals (A, B) and 20mm PVC laterals (C, D) after leveling of girdle sprinklers*

Flow rate variation under lower pressure

Flow rate variation was reduced up to 33% in girdle sprinklers at 16 mm conduit laterals and up to 21% in girdle sprinklers at 20 mm PVC laterals. Girdle sprinklers with PVC laterals show better uniformity than conduit laterals. However the present flow variation within a particular lateral is due to the pressure reduction and due to the variation of orifice diameters in girdle sprinklers. Therefore a proper mechanism should be developed to prepare girdle sprinkler orifices with exact dimensions.

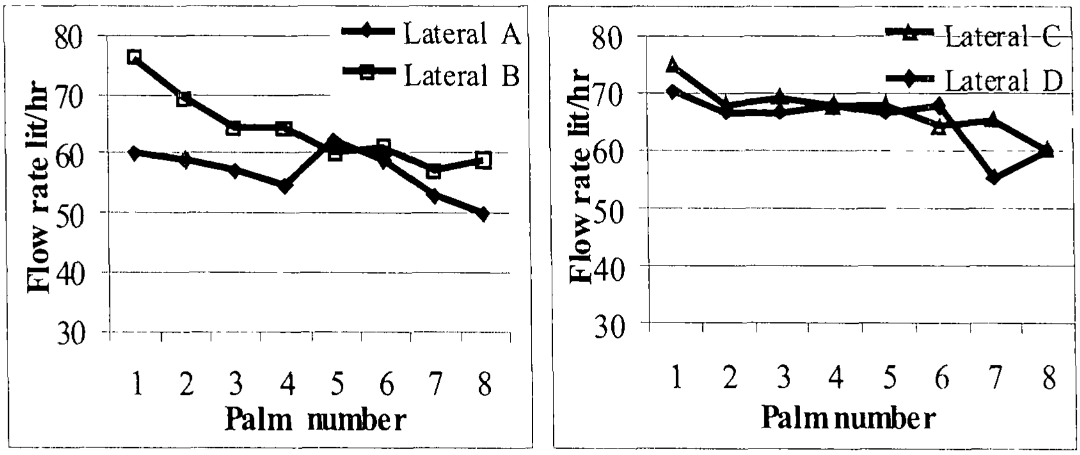

Fig.9. *Flow rate change along the 16mm conduit laterals (A, B) and the 20mm PVC laterals (C, D) under lower pressure*

Flow rate variation with the sub main in the middle of the system

Once the sub mainline is shifted to the middle of the system the whole uniformity of the water application is increased with mean flow rates for PVC system and conduit system showing 66.86 liters/hour and 68.95 liters/hour respectively. Results are shown in Fig. 10. Maximum flow rate difference for girdle sprinklers with conduit laterals is 13.46 liters/hour and it is 9.42 liters/hour for girdle sprinklers with PVC laterals.

However even after a series of modifications still the system shows some variation in the application of water. This is basically due to the errors in girdle sprinklers made in the laboratory scale. Results from the unique girdle sprinkler shows the best result as shown in Tables 1 and 2. Manufacturing defects were over come by this modification. The maximum flow rate difference for conduits is 5.98 liters/hour while the mean flow rate is 96.14 liters/hour. The highest accuracy was achieved with this modification since all orifices have exact 1mm diameter. On the other hand girdle sprinklers with PVC laterals show 5.26 liters/hour flow rate variation from 100 liters/hour to 94.74 liters/hour. The mean flow rate is 96.87 liters/hour.

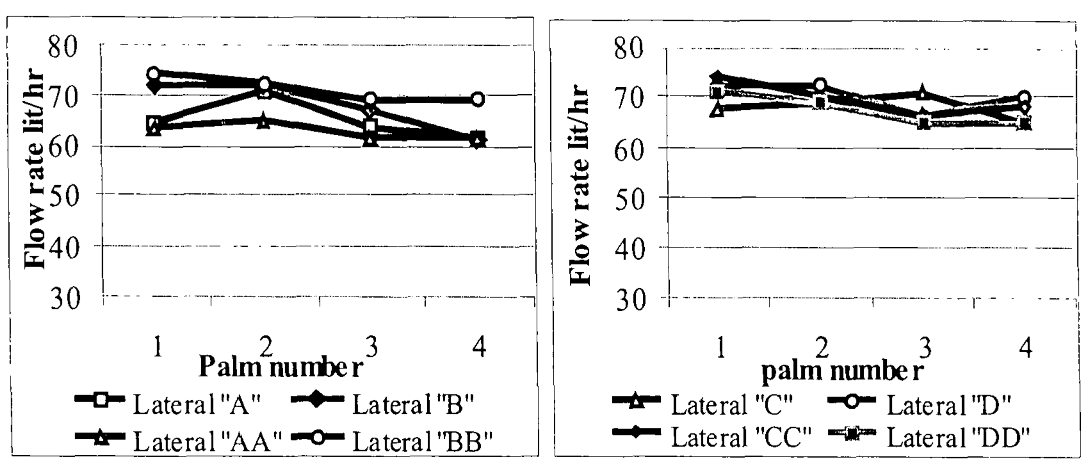

Fig. 10. *Flow rate changes along the 16mm conduit laterals (A,B,AA,BB) and 20mm PVC laterals (C,D,CC,DD) when the sub main line in the middle*

Table 1. *Flow rate variation along the 16 mm conduit laterals with a unique girdle sprinkler*

Palm Number	Lateral A (lit/hr)	Lateral B (lit/hr)	Lateral AA (lit/hr)	Lateral BB (lit/hr)
1	99.08	98.18	99.08	98.18
2	96.43	94.74	97.30	97.30
3	95.58	93.10	94.74	96.43
4	94.74	93.10	96.43	93.91

Table 2. *Flow rate variation along the 20 mm PVC laterals with a unique girdle sprinkler*

Palm number	Lateral C (lit/hr)	Lateral D (lit/hr)	Lateral CC (lit/hr)	Lateral DD (lit/hr)
1	97.30	98.18	96.43	100.00
2	97.30	96.43	96.43	96.43
3	97.30	97.30	94.74	96.43
4	97.30	95.58	96.43	96.43

Water distribution uniformity

The Table 3 shows that the percentage of uniformity values of different modifications of girdle sprinkler irrigation system with different diameters of lateral and drip irrigation system. According to the water distribution uniformity rating (Peacock and Handley., 1998), the girdle sprinkler irrigation system with16 mm conduit laterals, the sub-mainline in middle modification is an excellent system for irrigation of coconut. The uniformity value for this system is 91%. Similarly after leveling of girdle sprinklers, after looping laterals, operated with low pressure water pump and sub-mainline in middle modifications of 20mm PVC laterals girdle sprinkler irrigation systems are excellent systems (Those values are 91%, 91%, 90% and 94% respectively).

The girdle sprinkler irrigation system with 20 mm PVC laterals gives much uniformity of water distribution to the irrigated area than 16mm conduit laterals girdle sprinkler irrigation system. Because of the pressure losses is less in the 20mm PVC laterals girdle sprinkler irrigation system.

Table 3. *The uniformity values (%) relevant to each modifications of girdle sprinkler irrigation system and comparison with drip irrigation system*

Type of lateral	Before leveling	After leveling	After looping	With 1" pump	Sub-main in middle	With same girdle	Drip irrigation system
16mm Conduit	83	86	88	89	91	97	87
20mm PVC	75	91	91	90	94	98	

CONCLUSION

The results obtained on PVC laterals and conduit laterals show that PVC laterals, which has 20 mm diameter are better than conduit laterals which has 16 mm diameter for girdle sprinkler irrigation

The girdle sprinkler system, which comprise one kg cm^{-2} inlet pressure with sub-mainline in middle of the field, having 20 mm PVC laterals has 94 % of distribution uniformity. The same system with 16 mm conduit laterals had 91% of distribution uniformity. Therefore, this irrigation system is a viable method for small scale coconut cultivation.

The distribution uniformity of the girdle sprinkler irrigation system can be further increased by producing girdle sprinklers with standard levels.

This system conserves water as well as labour compared to hose irrigation. It also has less clogging incidence compared to drip irrigation so that even harvested rain water or water with silt parts can be used to irrigate with just a screen filter.

The total cost for one acre girdle sprinkler irrigation system with PVC laterals is Rs: 32,800.00 compaired to Rs: 31,000.00 with conduit laterals (excluding the water pump).

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