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Applying the Hardy Cross method to assess the energy-saving associated with closed circuits in drip irrigation systems compared to open circuits

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The analysis of a looped water distribution system, usually employed in subsurface drip irrigation (SDI), under pressure and steady-state conditions, can be successfully performed if the topology of the network, the structure pipes, and the discharges at the nodes are known (Wang et al., 2021). Solving these complex networks usually requires an iterative approach. The Hardy Cross method (HCM), which was originally developed in 1936 (Cross, 1936) for manual calculations in civil engineering, can also be applied in lopped drip irrigation systems. This approach relies on the successive addition of flow-rate adjustments in each pipe to achieve the energy balance in each network segment, although limited by the Darcy-Weisbach resistance equation where the discharge exponent is set to 2.

In this work, a reformulated HCM was applied to looped drip irrigation systems, considering both local losses due to emitters' insertion and the Hazen-Williams resistance equation (discharge exponent = 1.852), which is better suited to describe friction losses in the commonly used polyethylene pipes. The hydraulic performance of closed circuits calculated by HCM was analysed and compared with that of open circuits designed by IRRILAB software application (Baiamonte, 2018).

In particular, the final objective is to assess the energy-saving provided by the closed circuits (cc) in drip irrigation systems with respect to open circuits (oc). The energy-saving amount is expressed as the ratio (h_{ratio} < 1), between the inlet pressure head, h_{in}, of the closed circuit and that of the open circuit. A predictive relationship of h_{ratio} was calibrated for 3000 simulations carried out for rectangular irrigation units characterized by different geometry, pipe diameters, emitters' spacing and flow rate, providing relative errors RE < 0.25%. The results show that h_{ratio} depends on the pressure head tolerance of the manifold, δ_M, associated with the open circuits, which IRRILAB requires as an input parameter. This is very reasonable since, for high δ_M, the discharge circulating in the manifold is also high and closing the circuits provides low h_{ratio} ($h_{in}\ cc \ll h_{in}\ oc$). The vice versa occurs for low δ_M. Contrarily, the number of drip laterals, N_{rows}, has only a marginal effect on h_{ratio}. Of course, the energy-saving benefit should also consider the higher investment costs of cc than oc. However, this issue is beyond the scope of this study.

Keywords: Hardy-Cross method, Drip irrigation systems, Closed and open circuits, Pressure head

tolerance, Energy-saving.

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