Selecting Irrigation Systems for Vegetable Crops in Brazil

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Keywords: irrigation systems, irrigation efficiency, selection criteria, economic analysis

Abstract

Vegetable crop yield and quality may be strongly influenced by the irrigation system. Although sprinkle irrigation systems are the most used in Brazil, no system can be considered adequate for all conditions. The correct irrigation system selection depends upon technical and economical analysis. A brief description and usage of the main irrigation systems are presented in this paper and the major factors affecting vegetable crop irrigation adequacy and performance are discussed. A simplified selection methodology is presented and a case study is shown for better understanding of the proposed procedure.

INTRODUCTION

The development of vegetable crops is strongly influenced by soil moisture conditions. Soil water deficit becomes a limiting factor to obtaining good yields and product quality even in humid and semi-humid regions. Therefore, supplementing plant water needs through irrigation is fundamental for vegetables production success. Both yield and quality may also be affected negatively depending upon which irrigation system is employed. The adoption of an inappropriate irrigation system may jeopardize the entire vegetable crop agribusiness due to yield and quality losses, high vegetable production costs, and high investments usually required to acquire the irrigation equipment.

Although sprinkle irrigation systems are by large the most used in Brazil, no system can be considered adequate for all conditions or able to meet all expectations. The correct selection of the system must be based on detailed and careful analysis of environmental, agronomic, and economic factors.

A brief description of the main irrigation systems and their usage in Brazil are presented and the major factors affecting vegetable crop irrigation adequacy and performance are discussed. A simplified selection methodology is presented and a case study is shown for better understanding of the proposed selection procedure.

IRRIGATION SYSTEMS

No irrigation system can be considered adequate for all conditions, since all of them carry their own characteristics. Therefore, in the process of choosing an irrigation system there must have a compromise among the many different attributes that are related to each system. Following, major aspects of the main systems are raised for the sake of facilitating the decision making process.

Surface systems usually require fewer investments on equipment and energy consumption is usually lower than other systems. However, they depend heavily on land forming and are not recommended for soils with high permeability. Furrows are employed mostly for staked crops such as fresh-market tomatoes. Watermelons, melons and onions also use this system to some extent. Small, temporary flooding, level basins have been used for onions production by small farmers in the São Francisco Valley.

Water table management is a major possibility of subsurface system although it has not been used significantly. Experimental results reported by Marouelli and Silva (1991) indicated that water table management is feasible to irrigate crops such as garlic, green beans and sweet corn. Carrots and onions did not adapt well to this system.

Conventional sprinkle are the most used systems to irrigate vegetable crops in Brazil especially in small farms. For larger areas, center pivots have been utilized to

Proc. 9th IS on Field Vegetables
Eds. D.J. Cantliffe et al.
Acta Hort. 607, ISHS 2003

irrigate processing tomatoes, peas, potatoes, garlic, watermelons and carrots to a lesser extent.

Microsprinkle and drip irrigation are the main microirrigation systems. Protected cultivation and plastic mulched vegetables use mostly drip irrigation. In spite of its many advantages there are some limiting factors to the growing of this system usage, such as the need of frequent lateral removals as consequence of the relatively short growing season of vegetables and higher investments. Subsurface drip irrigation appears to have potential for vegetables production in Brazil due to its advantages as compared with other systems. One of these advantages is the lower incidence of diseases and consequently less spraying is needed. Silva et al. (1997) and Silva et al. (1999) have shown promising results using this system on bell peppers, fresh-market and processing tomatoes.

FACTORS AFFECTING SYSTEM SELECTION

Agronomic Factors

Vegetables characteristics such as plant size, row and plant spacing, planting density, plant training or pruning systems, rooting system and crop water requirements are the major agronomic factors related to the process of irrigation system selection. In general, row crops are more suitable for furrow or drip irrigation. Sprinkle systems are the most versatile ones although there are some aspects such as crop height and the use of plastic mulch that may affect the efficiency of these systems. Furthermore, there are some crops that may have yield affected by sprinkling during the flowering stage.

Disease and Insect Factors

Systems which apply water to plant foliage in general favor pests and disease development and damage, especially if they are poor managed. Besides that the process of sprinkling washes out chemicals that are used to control diseases and insects. However, there are some diseases and pests that are better controlled when using sprinkle irrigation for instance. In these cases, fungi spores, insect larvae and eggs are washed out and the control is attained to a certain extent.

Soil, Topographic and Climatic Factors

High infiltration capacity soils are not recommended for furrow irrigation but have minimized or no problem for sprinkle and surface drip irrigation. However, low infiltration rate soils may bring about waterlogging and runoff problems due to its easiness of surface ponding and difficult drainage.

Sloping soils or rough terrain have problems only with surface systems, since pressure regulators and self-compensating emitters can be employed to compensate for topographic problems.

Wind speed, air temperature and relative humidity are the most critical climatic factors to consider when selecting irrigation systems. These factors affect crop water requirements but the most important problems are related to water distribution uniformity and application efficiency of sprinkle systems. High wind speeds distort distribution patterns, and along with high temperature and low humidity facilitate water droplets evaporation.

Economic Factors

Several variables must be taken into account when performing economic analysis for selecting irrigation systems and this makes the selection process very complex in most cases. The relationship between fixed and variable costs of irrigation and the benefits resulting from the adoption of determined irrigation system can be predicted by means of an economic analysis in which all annual expenses and revenues are estimated. In general, surface systems are associated with the lowest cost per unit of irrigated area whereas microirrigation systems are the most expensive ones.

Other Factors

Several other factors have important roles on the irrigation system selection for vegetable crops. Water shortage limits the selection to systems that use less water as drip irrigation for instance. High salt content water is more recommended for drip systems as long as the saline concentration will not affect the vegetable crops. High carbonate concentration in water may plug emitters in drip systems. Contaminated water should not be used for the irrigation of vegetables mainly when the water is sprinkled over edible parts of the plants.

Factors such as application efficiency and distribution uniformity are also important to be considered. Besides wasting water and energy, low efficiency systems may affect crop yield and quality. In general, drip systems are associated to higher efficiencies followed by sprinkle and furrows systems.

The possibility of applying agricultural chemicals, such as fertilizers, fungicides and insecticide to the crops, via irrigation water, is also an important factor. Theoretically, it is possible to apply chemicals utilizing all the existing systems but there are some systems that are more suitable to the process. Most of chemigation practiced in vegetable crop production is fertigation and the most feasible system is drip irrigation. As a matter of fact, it is not intelligent to use drip systems without performing fertigation.

Lately, many vegetables growers have turned to irrigation system automation as an alternative to overcome labor shortage. Again, it is possible to automate the irrigation process using most of the known systems, but sprinkle and, mainly, drip systems are the ones most appropriate for automation.

SELECTING PROCEDURE - A CASE STUDY

Basic Information

In order to exemplify the proposed procedure to select irrigation systems a case study is presented, considering an area of 80 ha of processing tomatoes growing in the "cerrados" of Central Brazil. It is assumed that the terrain is slightly undulated and there are no constraints in terms of water quality, climatic conditions, shape of the area, and depth of water table. Furthermore, the clay soil has a water holding capacity of 1.1 mm/cm, basic infiltration rate of 20 cm/h, the crop consumptive use is 400 mm/season, wind speed is less than 2 m/s and the pump lift is 25 m.

Pre-Selection

Given the basic information a pre-analysis should be performed considering all the negative and positive characteristics of the existing irrigation systems and of the prevailing overall conditions. First of all, flood and border irrigation systems were not considered because they favor the occurrence of diseases which reduces tomato crop yield. Furrows were not recommended due to the high soil infiltration rate. Furthermore, there are no favorable conditions for creating and managing the water table. Microsprinkle requires high investment and does not present advantage as compared to other sprinkle systems. Lateral move and side-roll systems were also discarded due to lack of tradition with these systems in the country. Therefore, technically selected systems were: drip, center pivot, solid set and semi-portable conventional sprinkle systems. Dealer technical assistance, maintenance, spare parts and labor were not considered as limiting factors for the selection of any system.

Economical Analysis

The final selection is based on the economical analysis of the pre-selected systems by calculating the individualized annual cost and income. The total annual cost included fixed and variable costs of each irrigation system and the production cost of the crop. Total income was considered as the amount of money obtained from selling crop production. The total annual fixed cost was obtained from adding the depreciation (D_{ma}) and the capital opportunity costs (J_{ma}) of the value of the irrigation system:

$$D_{ma} = \frac{\text{purchase value - sale value}}{\text{lifetime (years)}} \qquad J_{ma} = \frac{\text{interest rate}}{100} \times \frac{\text{purchase value + sale value}}{2}$$

The resale value of the systems was considered negligible and annual interest rate was assumed 6%. The variable costs are: operational (energy, labor and water) and maintenance costs. The annual maintenance cost, which included the cost of spare parts, labor and lubricants, was calculated as a fraction of the equipment acquisition cost (Table 1).

Irrigation labor cost was US$ 1.30/hour/worker, manual harvest US$ 7.50/t and the production transportation was R$ 7.50/t considering a distance of 100 km. Electric power rate, considering power demand, was US$ 0.065/kWh for center pivot and drip irrigation, assuming that 50% of irrigation is performed during night time, which has an 80% discount over the normal rate. For semi-portable sprinkle system the price was US$ 0.115/kWh assuming that crop was irrigated during day time. Tomato production value was assumed as US$ 50.00/t. Water was obtained at no cost as it usually is in the region. Additional information for the economical analysis are in Table 1. Information about equipment life time, labor use, maintenance costs and energy requirements were obtained from Keller and Bliesner (1990), James (1993) and Sacalopi (1985). Irrigation systems and production costs and tomato yield were obtained from irrigation equipment dealers, processing plants and growers.

RESULTS AND DISCUSSION

Economical analysis results are presented in Table 2. The annual net income per hectare was US$ 540, 526, 358 and 79 for center pivot, drip, solid set and semi-portable conventional sprinkle systems, respectively. Center pivot presented the highest income/cost ratio (1.16) as compared with other pre-selected systems. Also, it has the lowest initial acquisition cost about 46% and 48% as compared to drip and solid set sprinkle systems, respectively. Therefore, center pivot is the system technically recommended and it is the one providing the best economical performance for the given conditions.

CONCLUSIONS

Irrigation systems selection is not a straight forward procedure nor can it rely only on practical information and calculations. Some experience and common sense must be applied in order to select the system that will best suit each particular condition. As in the above case study, besides using all given data there are some further details that must be considered. First of all, it should be observed that only the tomato crop was considered in the economical analysis. If there was another irrigated crop following tomato it would also have to be taken into account in the calculations of the economical indicators. Secondly, it is not recommended to use rotation crops that favor the development and buildup of pest and diseases in the soil. Rotation crops most recommended for tomatoes are maize, wheat and rice. Although these crops make processing tomatoes crop more feasible in the same area for longer periods, sometimes they do not bring economic revenues to the farmer.

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Tables

Table 1. Initial cost of pre-selected systems and factors considered in the economical analysis.

Components/factors	Drip	Center pivot	Solid set	Semi-portable
System initial cost (US$/ha)[a]	1,300/1,300[b]	1,300	2,500	1,000
Lifetime (years)	10/3[b]	15	15	10
Use of energy (kWh/m^3)	0.25	0.35	0.40	0.50
Irrigation efficiency (%)	90	80	75	65
Volume of pumped water (m^3/ha)	4,444	5,000	5,333	6,154
Labor usage (worker/ha/irrigation)	0.3	0.2	0.4	2.0
Number of irrigations per season	50	24	24	24
Maintenance cost [c]	2.0/5.0[b]	5.0	4.0	5.0
Production cost (US$/ha)[d]	1,800[d]	1,950	1,950	1,950
Crop yield (t/ha)	90	80	80	75

[a] Including pump, pipes and fittings costs for water distribution.
[b] First figure refers to irrigation system without irrigation laterals; the second refers to the laterals.
[c] Percent of initial investment.
[d] Lower in relation to sprinkle due to less amount of chemicals spraying.

Table 2. Fixed and variable annual irrigation costs, production cost and total income, for pre-selected systems (US$/ha)

Costs and Income	Drip	Center pivot	Solid set	Semi-portable
Fixed costs of irrigation				
Depreciation	563.33	86.67	166.67	100.00
Capital opportunity	78.00	39.00	75.00	35.00
Variable costs of irrigation				
Energy	72.22	113.75	138.67	353.85
Labor	19.50	6.24	12.48	62.40
Maintenance	91.00	65.00	100.00	50.00
Production costs				
All except irrigation	1,800	1,950	1,950	1,950
Harvest and hauling	1,350	1,200	1,200	1,125
Total costs	3,974	3,460	3,642	3,671
Total income	4,500	4,000	4,000	3,750
Total income – Total cost	526	540	358	79
Income/cost Ratio	1.13	1.16	1.08	1.04