Efficiency, cost, optimization and spread of spray irrigation in West Africa

Abstract

Spray irrigation is a low-cost, overhead system that consists of a small petrol pump (Honda, Yamaha, Robin) with a lay-flat hose of 40 or 50 mm diameter at the end of which is a hand-held spraying head of the type normally found on watering cans. Its use by professional market gardeners was observed in Togo, Niger and Mali in 2000 and 2001. Spray irrigation is energy efficient, water efficient, adapts well to the yield limitations of low-cost, hand-dug wells, is readily available, and poses no problems in terms of technology transfer. There are various options for optimization: (1) reducing the price of equipment, including that of accessories, such as layflat hose; (2) improving spraying head efficiency; (3) improving pump efficiency; (4) improving engine efficiency; and (5) replacing the petrol pump with a treadle pump. It is recommended to collect information on existing spray systems to enable their cost and efficiency to be compared with those of fully developed technologies, such as sprinkler and trickle irrigation.

Origin

Its use by professional market gardeners was observed in Lomé, Togo, but also Niamey in Niger and Bamako, Mali (Van ’t Hof, 2001a and b). It resembles stationary spraylines. Over the past few years, spray irrigation technology spontaneously spread across West Africa, i.e. from farmer to farmer and without the assistance of development organizations. A recent survey in Bamako among 80 market gardeners with small petrol or diesel pumps showed that more than 60% use spray irrigation (Maurice, 2002). Farmers in Bamako did not know of its use elsewhere in West Africa and considered it a local invention that dates back to about 1998.

Evolution

Spray irrigation probably evolved directly from the use of watering cans where water is drawn from storage basins, wells or a surface source (river, lake, reservoir)

Market gardening in Bamako

In the Bamako-type of spray irrigation, the length of the lay-flat hose is 25-50 m and its diameter is 40 or 50 mm. The spraying heads are locally made. So far, no measurements have been made of their dimension, number and size of holes, or discharge/pressure relationship.

In a 0.5 ha vegetable garden, there may be 5 wells. A portable, self-aspiring pumpset is carried from one well to the other to empty them one by one. With a discharge of 1-2 l/sec, it takes 15 to 30 minutes to empty each well, a bit less during the dry season when the groundwater level reaches a seasonal low with a static head of 2.5 m below the surface. The static water level in the well is between 0.5 and 2 m, depending on the season. Typically, the well diameter is 2 m at the surface and 1.5 m at the bottom. Fuel consumption is in the order of 0.5 l/hour.

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(considering the small storage in the well, water efficiency is of paramount importance)

Hydraulics of spray irrigation

The hydraulics of spray irrigation are very straightforward. The discharge of a spraying head can be calculated using *Torricelli's theorem* (v=(2*g*h)^0.5) corrected for flow through a sharp-edged orifice where the proper area to use for the jet cross-section is that at the smallest diameter at a point, called the *vena contracta*, slightly outside the orifice, as follows: Q = 0.62*A*(2*g*H)^0.5 (eq. 1), where Q is the discharge in m^3/sec, A is the area of the orifice in m^2 and H is the head in metres.

This was verified with a little test at home: with an average orifice diameter of 1.25 mm, the total orifice area A of the Deli watering can is 0.0002711 m^2. Using Eq. 1, Q = 0.37 l/sec and the volume emptied in 25 seconds is estimated at 9.3 litres, which is close to the observed value of 10 l.

Fuel efficiency of spray irrigation

A fuel consumption of 0.5 l/h suggests an engine speed of about 2500 rpm. Making a number of assumptions (see article) we find that:

- pump efficiency is 30%
- pump power is 0.56 kW
- engine efficiency 11.7%
- total dynamic head is 10.48 m
- operating pressure of the spraying head is 4.79 m
- discharge of 1.63 l/sec.

Such an operating pressure is well below the operating head required for sprinkler systems (10 to 30 m). It can be calculated that fuel consumption of a 10 m or a 20 m head rotary sprinkler is 26% to 80% higher compared to a Bamako watering can spraying head!

Irrigation efficiency of spray irrigation

Probably, spray system has irrigation efficiencies that are comparable to that of drip irrigation. It is not excluded that other advantages of trickle irrigation mentioned by the ASAE (1983), including enhanced plant growth and yield but with the exception of weed growth reduction, apply to spray irrigation.

Small pumpsets along the Niger

Anil (India)

Honda

Advantages of spray irrigation:

(1) its relatively low investment cost per unit area;
(2) widespread availability of equipment;
(3) well adapted to situations with multiple low-yielding wells, requiring the equipment to be shifted every 15 to 30 minutes;
(4) high application efficiency;
(5) probably enhanced plant growth and yield;
(6) negligible problems of rodent damage or theft;
(7) no emitters, so no emitter clogging; and
(8) African farmers quickly take up the technology.

Possibly, the main disadvantage is its labour requirement, but this will require further study for the case of multiple low-yielding wells.

Options for optimization:

- reducing the price of equipment, including that of accessories, such as layflat hose;
- improving spraying head efficiency;
- improving pump efficiency;
- improving engine efficiency; and
- replacing the petrol pump with a treadle pump.

These farmers know what they are doing

 

spraying & priming

Recommendations

- measure the net cultivated area among vegetable growers in Bamako;
- measure the uniformity and depth of application by setting small cans in a square grid in the vegetable beds;
- compare the depth of application with calculated evapotranspiration;
- measure the pressure-discharge relationship in spraying heads;
- if the typical pressure loss in spraying heads is about 4 m, ask farmers to try more efficient spraying heads with pressure losses of 1 to 2 m (see above);
- measure engine speed-fuel consumption relationships for typical user conditions;
- describe the well hydrology and measure well yields in different seasons;
- describe the cropping system over a full year in relation to dropping and rising groundwater levels in order to better understand how vegetable growers cope with water shortage at the end of the dry season;
- scout in countries, such as China, for affordable, low-lift pumpsets that are capable of a discharge of 1,5 to 2 l/sec at a total dynamic head of 5-8 m while maintaining reasonable engine and pump efficiency;
- examine the scope for using electric pumps, e.g. 220 V, 300-400 W submersible dewatering pumps; and
- check whether any progress has been made with improving the fuel efficiency of the Shandong SPP50-14 (PPIP/ANPIP, 2000).