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Effect of micro-sprinkler system on input use efficiency, labour cost and economic viability in tobacco (*Nicotiana tabacum*) seedling production

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ABSTRACT

To improve the water and nutrient use efficiency and also to reduce the labour cost in tobacco (*Nicotiana tabacum* L.) nursery raising, experiment on micro sprinklers for tobacco nurseries was conducted at CTRI Nursery block, Rajahmundry, Andhra Pradesh during 2007 and 2008. From the results of the experiment, it is concluded that the optimum spacing between laterals is 2.5-3.0 m and the spacing between micro sprinklers is 2.5–3.0 m and for this spacing 4 sprinklers are required for irrigating two tobacco nursery beds. The micro sprinkler system saves 24% and 35% of irrigation water at nursery bed level and at total system level respectively in comparison to rose can watering system. Micro sprinklers increases the N, P, K concentrations of the total plant to an extent of 14%, 10%, 11% and uptake per unit area to an extent of 50%, 45%, 47% respectively over the rose can watering. Micro sprinklers increases the weight, height, root volume and number of transplantable seedlings by 19%, 16%, 31%, 18% respectively over the rose can watering. Installing micro sprinkler irrigation system saves an amount of ₹ 60 000/ha towards labour. Micro sprinkler system is an economically viable alternate to rose can watering and gives net present worth of ₹ 94 265/ha/year with a benefit cost ratio of 2.37 at 2011 prices.

Key words: Economic viability, Labour, Micro-sprinklers, N, P, K uptake, Tobacco seedlings, Water saving

In India, tobacco is an important commercial crop, cultivated in about 0.4 m ha, earning ₹ 4 402 crores of foreign exchange and ₹ 13 853 crores of excise revenue, besides providing employment to 36 million people in the country (Tobacco Board 2012). At present, the tobacco exports account for 4% of total agri exports and the excise revenue from tobacco is more than 12% of the national excise revenue collection. However, there is need to enhance productivity and quality of Indian tobacco to make it more remunerative, globally competitive by adopting recent advanced technologies. Tobacco is high labour intensive crop and up to 50% of production cost goes towards labour (Sannibabu *et al.* 2007). The main source of irrigation in tobacco growing zones is tube wells and groundwater resources are depleting in these zones, due to over exploitation and in-judicious use of irrigation water. The present electricity supply in tobacco growing states is on rotational basis for limited hours (6 hr), i e during one fortnight it will be supplied in day hours and during next fortnight will be in night hours. Due to this power supply polices, farmers are interested in switching from traditional irrigation methods to micro irrigation systems so that they can cover more area with less time and manpower. Tobacco seed size is very small (10 000 seeds in one gram), due to that nursery is raised on raised beds and 60 days old seedlings are transplanted in main field. The establishment of good crop will depends upon the quality of the seedlings planted. In tobacco nurseries water is applied 3-6 times/day through rose-cans manually, which is labour intensive and involves high scale drudgery. Moreover there is labour shortage due to seasonality and high scale drudgery. It is also mentioned, that rose-can watering operation causes wetting of cloths of the labour as a result of which they are not much interested for this operation. Micro irrigation systems may help to overcome all these problems.

Research studies conducted in India by various researchers have indicated that water saving is about 40–80% and the yield increase is up to 100% for different crops by using micro-irrigation (Sivanappan 1994, Neelam and Rajput 2009, Rao *et al.* 2010, Singh *et al.* 2010). The benefit-cost ratio (B_I/C_D) worked out for various crops ranges from 1.35 to 13.35 excluding water saving and 2.78 to 32.32 including water saving (Sivanappan 1994, Rajput and Neelam 2007). Kumar *et al.* (2009) has reported that micro-sprinkler irrigation increases the yield and fertilizer use efficiency by 40%, 48% respectively. The yield response factor (ky) ranges from 0.45 and 0.42 (normal irrigation) to

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1.72 and 1.70 (full deficit irrigation with micro sprinklers) for summer and *rabi* seasons, respectively (Thiyagarajan *et al.* 2010). Kumar *et al.* (2008) optimised the water requirement (280 mm) to get maximum potato yield with micro sprinkler irrigation system under semi-arid environment. Sarkar *et al*. (2008) developed different indices to characterize water use pattern of micro-sprinkler irrigated onion. Ahmed *et al.* (2000) reported that the overhead irrigated tomato seedlings had a higher dry weight and more leaves in comparison to sub irrigation. Klimek *et al.* (2008) reported that the height of one-year old Scots pine seedlings increased from 8.9 cm on control plots to 13.2 and 13.7 cm with micro-jet sprinkling and drip irrigation, respectively. Micro-sprinkler irrigation system offers high irrigation efficiency on account of reduced losses such as runoff and percolation as compared to other irrigation systems where drip-irrigation system is not feasible (Sankar *et al.* 2008). Superiority of drip irrigation or micro-sprinkler irrigation over traditional irrigation methods in terms of yield and water saving, economics is well established for most of the crops. But economic viability of applying micro-irrigation systems in tobacco crop or nurseries is yet to be addressed. Keeping these considerations in view, an experiment on micro sprinklers for tobacco nurseries was conducted to reduce the labour cost and improve water and fertilizer-use efficiency and its economic viability in tobacco seedling production.

MATERIALS AND METHODS

An experiment was conducted during 2007 and 2008 at Central Tobacco Research Institute (CTRI), Nursery block, Rajahmundry (16° 59' N and 81° 48' E at 25.3 m above mean sea-level) in East Godavari district of Andhra Pradesh to study the effect of micro-sprinklers on growth and number of transplantable seedlings, water saving, nutrient uptake, labour cost reduction and its economic viability in tobacco seedlings production. The region is a hot dry sub humid agro-ecological sub-region (semi-arid tropical climate) with an average annual rainfall of 1100 mm. The soil of the experimental site is sandy loam.

Micro-sprinkler system components (sub main, laterals, sprinklers etc.) were designed with the help of standard micro irrigation design procedures (Rajput and Neelam 2007). In this study, it is considered that, water requirement for tobacco seedlings are equal to reference evapotranspiration (ET_0) because the seedlings growing conditions are considered to be same as defined in reference evapotranspiration conditions. In this study water requirement (equal to reference evapotranspiration) for tobacco seedlings were determined by pan evaporation method and estimated by the following equation (Doorenbos and Pruitt 1977, Allen *et al.* 1998).

$$ET_0 = kp \times E_{pan} \quad (1)$$

where, ET_0, Reference evapotranspiration (mm/day); K_p, Pan coefficient; E_{pan}, Pan Evaporation (mm/day).

The pan evaporation data from a meteorological observatory located in CTRI, research farm, Rajahmundry were used to calculate ET_0. For the study area pan coefficient (K_p) of 0.82 was selected from Irrigation and Drainage Paper 56 (Allen *et al.* 1998) to estimate ET_0 from pan evaporation. The standard bed (plot) size of 10 m × 1.2 m was considered for treatment and control. In control plot, water was applied daily 3-6 times with rose-cans by manually (Fig 1a) and in micro-sprinkler plots, daily estimated quantity of water was applied in 3 to 4 waterings (Fig 1b). The recommended doses of fertilizers in micro-sprinklers and control plots were applied manually.

To apply the required amount of water uniformly to all the plants in the field, better crop and optimal cost of the system; it is essential to determine the optimum geometry (spacing between laterals and sprinklers) of the system under desired hydraulic pressure in the pipe network based on crop performance and soil water dynamics. To determine the optimum geometry, coverage/swath width of a micro sprinkler, seedlings performance, soil moisture under different spacing and operating pressures were recorded and analyzed. The optimum geometry was determined based on seedlings performance, coverage/swath width and soil moisture. From this geometry optimum spacing between laterals and sprinklers was determined and with this spacing number of sprinklers required per standard tobacco nursery beds was determined.

a) Manually with rose-cans b) Micro-sprinklers

Fig 1 Water application to tobacco nurseries by manually with rose cans and micro-sprinklers

In FCV tobacco cultivation seedlings are raised on nursery beds and these seedlings are pulled and transplanted in fields. The establishment of good crop depends upon the quality of the seedlings planted. The growth of seedlings and number of transplantable seedlings in unit area depends on the availability of nutrients and water etc. In this study, to determine the nutrient uptake, 40 days old seedlings were pulled and these plant samples were dried in hot air oven and the dried samples were processed and analysed for total nitrogen (TIM 1977), phosphorus, potassium (Jackson 1967) from this concentration and dried weight of the seedlings uptake per unit area of the bed was determined. The seedling growth parameters such as height, weight, root volume, and number of transplantable seedlings were recorded in micro sprinklers irrigated plots and rose-can watering plots. The root volume was recorded by immersing fresh roots in a measuring cylinder by water displacement method. The t - test was used to analyze the data.

Digital water meters were installed in the pipe line of micro-sprinkler irrigation and rose-can watering system. For each watering, quantity of water applied was recorded during nursery growing period of 90 days. Under rose-can watering system, farmers make the small pits (around 10-15 pits/ha) and fill the pits with water by pumping system. After filling the pits, they will use these filled water for watering the nursery beds by rose cans. Total quantity of water delivered to the pits was calculated by the water meter data. Total water applied to the nursery beds by rose-cans during the nursery growing period was calculated based on the number of cans applied and volume of each can. From these recorded quantities, total water saving by the micro-sprinkler system was calculated at nursery bed level without inclusion of seepage and evaporation losses in pits and channels and total system level with inclusion of seepage and evaporation losses in pits and field channels.

Partial budget analysis was done to assess the change in costs and returns for switching to micro-sprinkler irrigation from rose-cans watering method. The variable costs considered were those on account of labour and maintenance cost of sprinkler system. Fixed costs, on the other hand, include depreciation, interest on investment, and insurance of the system. For the purpose of analysis, depreciation was computed following straight line method considering 7 years life of the sprinkler irrigation. Financial analysis was done following discounted cash flow technique. For this a discount rate of 8% was considering r an economic life of sprinkler system equal to 7 years. Prices prevailed in 2011 were taken for computation of different parameters. The cost of sprinkler system was taken ₹ 75 000/ha. Tobacco seedlings are sold in a batch of 6 000 Nos. During 2011, the seedling price realized at farm was ₹ 1 380/6 000 Nos.

RESULTS AND DISCUSSION

The data on micro sprinkler geometry on nursery beds, water applied, growth parameters, nutrient uptake and number of transplantable seedlings were analyzed and presented in the following sections.

Micro sprinklers geometry

The coverage/swath width of a micro-sprinkler, number of beds covered/sprinkler, soil moisture, number of transplantable seedlings/bed under different spacing and operating pressures are presented in Table 1. From the table it is seen that better soil moisture, optimum coverage, and more number of transplantable seedlings were observed under the spacing of 2.7 m with the operating pressure of 1.25-1.5 kg/cm^2. From the table it is also observed that under lower operating pressure (0.75-1 kg/cm^2) with spacing increases from 1.5 to 2.7m, it was overlapping for single bed and not fully covered for two beds. Under higher operating pressure of 1.75-2 kg/cm^2 with the spacing increases from 2.7 to 4.2 m, it was not fully covered for three beds. Most of the pumping systems are able to develop the operating pressure of 1.25-1.5 kg/cm^2 and these at high as well as low operating pressure conditions are not feasible. Under the operating pressure of 1.25 to 1. 5 kg/cm^2, the swath width/coverage diameter per sprinkler is 2.5 m-3 m. For this coverage, one sprinkler can cover two beds on each side and length wise it can cover up to 2.5-3 m length of the nursery bed. Based on this coverage, soil moisture, and number of transplantable seedlings for this coverage, it is inferred that the optimum spacing between laterals is 2.5 -

Table 1 Geometry of micro-sprinklers under different operating pressures and their performance

Operating pressure (kg/cm^2)	Sprinkler spacing (m)	Sprinkler placement	Swath width/ coverage (m)	Number of beds covered/ sprinkler	Soil moisture (%)	No. of transplantable seedlings/m^2 bed
0.75	1.5	At the centre of the bed (overlapping)	0.8	1	20.28	712
1.00	2.7	Between two beds (one bed on each side of the sprinkler), but completely not covered	1.0	2	11.10	624
1.25	2.7	Between two beds (one bed on each side of the sprinkler)	1.25	2	16.42	750
1.50	2.7	Between two beds (one bed on each side of the sprinkler)	1.5	2	16.43	756
1.75	4.2	Between three beds (on the centre of the second bed) but not completely covered	1.8	3	12.48	596
2.00	4.2	Between three beds (on the centre of the second bed)	2.0	3	13.16	680

3.0 m and the spacing between micro-sprinklers is 2.5–3.0 m. For this spacing laterals along with micro-sprinklers are placed in between two beds of each having size 1.2 × 10 m. For this geometry, 4 micro-sprinklers are required for irrigating two standard tobacco nursery beds, each having size 1.2 × 10 m.

Water saving

In rose-can watering system, total water delivered in the field during nursery period of 90 days is 5 047 m^3/ha. Out of this amount of water, 4 297 m^3/ha of water is actually applied to 1 ha of nursery bed through rose-cans and remaining 750 m^3/ha water is lost in field as seepage and evaporation in pits and channels. Under micro-sprinkler system total water applied for nursery beds through micro sprinklers during nursery period of 90 days is 3 255 m^3/ha. The micro sprinkler system saves 1 042 m^3/ha (24%) at nursery bed level and 1 792 m^3/ha (35%) at total system level which includes losses in pits and field channels in comparison to rose can watering. This saved water can be utilized for irrigating 0.55 ha additional nursery area through micro sprinklers. This much of water would not be withdrawn from the wells, thereby, reducing the pressure on groundwater.

Uptake, growth and number of transplantable seedlings

The N, P, K concentration, uptake of the seedlings and soil moisture is presented in Table 2. From the table it is observed that N, P, K concentrations, uptake and soil moisture under micro-sprinklers is highly significant over the rose-can watering. The N, P, K concentrations are increased up to 14%, 10%, 11% and uptake increased up to 50%, 45%, 47% respectively with the micro sprinkler system over the rose can watering. The higher concentration and uptake of nutrients under micro sprinkler system is mainly due to better availability of moisture and thereby enhancing the nutrient uptake (Table 2). The conductivity of the soil increases when soil moisture content is high and under such condition, mass flow transport of nutrients increases (Tisdale *et al.* 1985). It also might be due to sound root-soil relation, which provides rapid diffusion of ions by reducing the path length of ion movement on one hand and increase in elongation, turgidity and number of root hairs which ultimately, boost uptake on other hand. The present findings are also supported by Janat (2007), Singh *et al.* (2007), and Patel *et al.* (2012). The data on seedlings growth parameters and number of transplantable seedlings are presented in Table 3. From the table, it is observed that weight, height, root volume and number of transplantable seedlings are significantly higher for seed beds irrigated by micro sprinklers irrigation in comparison to rose-can watering (Table 3). The number of transplantable seedling production under micro-sprinklers and rose cans watering are 756/ sqm, 640/sqm of bed, respectively. The fresh weight, dry weight, height, root volume and number of transplantable seedlings under micro sprinklers are increased by 19%, 12%, 16%, 31%, 18% respectively over the rose can watering system. More number of roots and root volume was observed in seedlings irrigated by micro-sprinklers in comparison to rose-can watering. This is favorable for good establishment of seedlings in the field and reduces gap filling of plants in field. It is also observed that the seedlings growth under micro-sprinkler is rapid and is ready for transplanting in 50 days as compared to 60 days in conventional water application. The similar trend was also reported by Klimek *et al.* (2008) in case of Scots pine seedlings. The better uptake, growth parameters and number of transplantable seedlings under micro-sprinklers irrigation is mainly due to better availability of moisture and nutrients in the root zone of the plant. The micro-sprinklers might have created the favourable micro climate for better growth and more number of transplantable seedlings production. Similar findings were reported by Sasani *et al.* (2006) and Patel *et al.* (2012)

Economic analysis

The net profit increases by 19% with sprinkler irrigation. The breakeven price of seedlings works out to be ₹ 0.09. Farm budget analysis has revealed that installing micro sprinkler irrigation system would result in an additional income of ₹ 166 750/ha on account of transplantable

Table 2 Nutrients concentration and uptake of tobacco seedlings under micro-sprinklers and rose cans

Nutrients	Treatment	
	Micro-sprinklers	Rose cans
Concentration (%)		
Nitrogen	1.96 a* (14)	1.72
Phosphorous	0.34 a* (10)	0.31
Potassium	3.97 a* (11)	3.56
Uptake(g/m^2)		
Nitrogen	9.42a* (50)	6.27b
Phosphorous	1.64a* (45)	1.13b
Potassium	19.08a* (47)	12.95b
Soil moisture (%)	16.42 a*	13.26

* Means within the same row followed by same letter differ based on 't' test at 0.05 probability level. The values in parenthesis are percent increase over the control (rose cans)

Table 3 Growth and number of transplantable tobacco seedlings under micro-sprinklers and rose cans

Particulars	Treatment	
	Micro-sprinklers	Rose cans
Root volume of 50 seedlings (ml)	46.5a* (31)	35.4b
Mean height of seedling (cm)	9.8a* (16)	11.4b
Fresh weight of 50 seedlings (g)	354a* (19)	297b
Dry weight of 50 seedlings (g)	31.8a* (12)	28.4b
Days to transplanting	50a* (-17)	60b
Total number of transplantable seedlings/m^2 bed	756a* (18)	640b

* Means within the same row followed by same letter differ based on't' test at 0.05 probability level.

seedlings with a labour cost saving of ₹ 60 000/ha. On the other hand, this would incur an additional cost amount to the tune of ₹ 24 000/ha on account of annual fixed cost of micro sprinkler system and its maintenance. The net saving works out to be ₹ 202 750/ha. Financial analysis of micro sprinkler irrigation gives a net present worth of ₹ 94 265/ha/year with a benefit cost ratio of 2.37. Further sensitivity analysis reveals that even a 50% decrease in seedling price would make the installation of micro-sprinkler system financially viable with net present worth being ₹ 11 223/ha and benefit-cost ratio, 1.16. Similar type results were also reported by Sivanappan (1994) and Rank (2007). The change in discount rate does not change the parameters drastically. These viability parameters suggest installing micro-sprinkler irrigation over the traditional rose-cans watering system is viable.

CONCLUSION

Based on sprinkler coverage, soil moisture, and number of transplantable seedlings it is concluded that the optimum spacing between micro sprinklers laterals is 2.5-3.0 m and the spacing between micro sprinklers is 2.5-3.0 m. For this spacing laterals along with micro-sprinklers are placed in between two beds of each having size 1.2 × 10 m and 4 sprinklers are required for irrigating two beds. The micro sprinkler system saves 35% of irrigated water and significantly increases the N, P, K concentrations and uptake, weight and volume of the tobacco seedlings over the rose can watering. The micro sprinklers irrigation in tobacco nurseries will give 18% of additional number of seedlings over the rose can watering. Micro-sprinkler system is an economically viable alternate to rose can watering which saves labour, improves the water and nutrient use efficiency and gives net present worth of ₹ 94 265/ha/year with a benefit cost ratio of 2.37 at 2011 prices. The study concludes that micro sprinklers are viable alternate to rose can watering system with substantial labour cost saving and additional returns.

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