www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(4): 587-591

www.thepharmajournal.com
Received: 22-01-2021
Accepted: 01-03-2021

Performance evaluation of rain pipe irrigation under solar photovoltaic pump

GR Kathiriya, GV Prajapati, AM Paghdal, HD Rank and SV Kelaiya

GR Kathiriya
Former Student, M. Tech
Soil and Water Conservation Engineering, Junagadh Agricultural University
Gujarat, India

GV Prajapati
Associate Professor, RTTC
Centre of Excellence on Soil and Water Management, Junagadh Agricultural University
Gujarat, India

AM Paghdal
Research Associate, RTTC
Soil and Water Conservation Engineering, Junagadh agricultural university
Gujarat, India

HD Rank
Professor and Head, Department of Soil and Water Conservation Engineering, CAET Junagadh Agricultural University, Gujarat, India

SV Kelaiya
Assistant Professor, Department of Renewable Energy Engg. CAET, Junagadh Agricultural University, Gujarat, India

Corresponding Author:
GR Kathiriya
Former Student, M. Tech
Soil and Water Conservation Engineering, Junagadh Agricultural University
Gujarat, India

Abstract
The need and demand of solar photovoltaic water pumping system has been increased in the recent years, as a stand-alone water pumping system to pump water in remote locations. Micro irrigation system, which includes mainly drip and sprinkler irrigation method require constant maximum water pressure for normal system operation and it is difficult under solar photovoltaic pumping system due to variation in intensity of solar radiation during a day. Rain pipe irrigation systems can easily working under fluctuating pressure as well as low pressure condition effectively. The rain pipe system recently introduced for irrigation needs to be evaluated for their performance under solar photovoltaic pump. A field experiment was conducted to evaluate hydraulic performance of rain pipe irrigation system under three operating pressure of 0.25, 0.50 and 0.75 kg cm^2 keeping length of rain pipe 30m and 4m spacing between two rain pipes. The average maximum solar radiation 621.26 W/m^2 was received at 1:00 pm. The average discharge and water horse power of solar photovoltaic system ranged from 4.19 to 4.92lps at operating pressure of 0.75 kg/cm^2 during 10:00 am to 4:00 pm. Uniformity coefficient, distribution uniformity, mean application rate was determined under various operating pressure using solar pump. Results revealed that the highest uniformity coefficient, distribution uniformity and mean application rate of 83.63%, 75.08% and 12.47 cm/h was obtained at operating pressure of 0.75 kg/cm^2 respectively.

Keywords: Rain pipe, hydraulic performance, uniformity coefficient, distribution uniformity, coefficient of variation, mean application rate

Introduction
Availability of power for agriculture sector is now becoming scarce, conventional electricity not supplied for sufficient time, and it is difficult to extend the electric grid to every location where it is needed for every farmer. Increasing energy demand constantly requires new technology, which is based on renewable energy resources. Out of the various renewable energy resources available, solar energy is the most promising as the sun gives out an enormous amount of heat and light. The photovoltaic powered water pump is one such application, which has received great attention in the past decades (Chandel *et al.* 2015, Ali *et al*. 2016). The use of PV based pumps is also location dependent, as the performance of photovoltaic devices is governed by several factors such as total incident radiation and temperature (Foster and Cota 2014) [17].
Moreover, an efficient use of available irrigation water is essential for increasing agricultural productivity for the alarming Indian population. As the population of India is increasing day by day, the pressure on agriculture is increasing in the same way (Arya *et al.*, 2017) [1]. The conventional method of irrigation has not been as efficient in the use of water thus resulting in excessive wastage besides creation of problems in many regions through water logging and salinity (Bhattacharya, 2007) [3]. There is need to improve irrigation efficiency through optimization of irrigation water under conditions of limited water availability. Under this circumstance, high application efficiencies can only be obtained by pressurized irrigation. In recent years, the more efficient pressurized irrigation systems such as drip, trickle and sprinkler irrigation has become more usable instead of open channel irrigation system to increase the water use efficiency (Cobo *et al.*, 2014) [5].
Irrigation system performance assessment is of high priority in irrigation research to solve the problem of irrigation development and management. It is obvious that many irrigation systems are performing below their capacity. This situation may lead to non-uniform and unreliable water distribution. A well designed pressurized irrigation system is very important in the realization of the objectives of the irrigation scheme such as maximizing efficiency and being cost effectiveness.

The irrigation system must also satisfy various demands while meeting minimum pressure requirements. Cost effective solutions that satisfy the hydraulic constraints of the system are always desired, however such a solution is very difficult to achieve when pressurized irrigation system run under solar photovoltaic pump. In such condition a newly introduced irrigation techniques like, rain pipe irrigation technique which can operate under low pressure also and is a best suited to grow vegetables crops and closely spaced crop like groundnut, onion, garlic etc. and it is adaptable for almost all types of soils.

Rain pipe is a flat hose pipe with thin wall to be punched micro holes continuously under certain distance on one side of the rain pipe, these holes are made with nano punching technology with a zigzag pattern to ensure uniform flow of water. The micro water spray produced by rain pipe will make it the mistiest irrigation system. It is much mistier and softer than traditional sprinklers. The factors like; Christiansen uniformity coefficient, distribution uniformity operating pressure affecting performance of sprinkler irrigation (Sourell *et al.*, 2003; Eisa *et al.*, 2010; Length *et al.*, 2011 and Salmeron *et al.*, 2012) [7, 12, 18, 19]. Rain pipe irrigation can be an alternate irrigation system of a mini sprinkler and drip irrigation. It is one of the best and latest methods for efficient utilization of irrigation water. It is an efficient method of application of water in which, the water is applied at high rate over short period of time with low pressure delivery system like solar photovoltaic pump. There is need to evaluate the hydraulic performance of rain pipe irrigation system under variable pressure, length and spacing under solar photovoltaic pump.

Materials and Methods

The experiment was conducted at the Research cum Demonstration Farm of Centre of Excellence on Soil and Water Management, Research Testing and Training Centre, Junagadh Agricultural University, Junagadh. It is located at 21.5°N latitude and 70.44°E longitude with an altitude of 82.92 meter above mean sea level.

The experiment was set up in the field consisted 5 hp AC solar photovoltaic pump. Determined average solar intensity (W/m^2), discharge (LPS) and water horse power generated by the solar pump. The rain pipe of 32 mm diameter having length of 30 laid on the field, the spacing was kept 4 m between two rain pipe. A matrix of catch cans was installed at ground level using 2m x 1m grid that cover the experimental area between two rain pipe. For the determination of Christiansen's uniformity coefficient (CU), distribution uniformity (DU), coefficient of variation (CV) and mean application rate (MAR), the rain pipe were operated for half an hour at three different pressures of 0.25, 0.50 and 0.75 kg/cm^2 and rain pipe spaced at 4m spacing under 30m length of rain pipe. The operating pressure was measured using digital manometer and a by-pass valve was used to regulate the pressure. The water emitted by the rain pipe was caught in catch cans placed between two rain pipes. Water depth in catch cans was recorded and then converted into depth of water in accordance with the cross sectional area of the catch can. Discharge of solar photovoltaic pump at different operating pressure was measured manually using volumetric method by collecting the water in 500 liters tank and calculated discharge of solar pump at one hour interval from 09:00 am to 05:00 pm. (Priyanka *et al.*, 2018) [15].

Water horse power is the minimum power required to move water. Diurnal variation of water horse power with respect to solar radiation in a day was calculated at one hour interval from 09:00 am to 05:00 pm based on discharge of solar pump operated at different operating pressure (0.25 kg/cm^2, 0.50 kg/cm^2 and 0.75 kg/cm^2) and it was calculated as per following equation.

$$\text{WHP} = \frac{Q \times H}{75}$$

Where

WHP = Water horse power,

Q = Discharge (LPS at respective operating pressure),

H = Head (m)

Determination of uniformity coefficient

A measurable index of degree of uniformity obtained from any size of sprinkler operating under given condition is known as uniformity coefficient. The uniformity coefficient was obtained by the following formula proposed by Christiansen. (Christiansen, 1942).

It is expressed by the

$$\text{Uc} = 100\left(1.0 - \frac{\sum x}{mn}\right)$$

Where

U_c = Uniformity coefficient developed by Christiansen, %

x = Absolute deviation of the individual observations from the mean, mm

m = Average value of all observations, mm

n = Number of observations

Determination of distribution uniformity

A useful term for placing a numerical value on the uniformity of application for irrigation system is the distribution uniformity (Du). The distribution uniformity is also known as pattern efficiency (P_e). It indicates the uniformity of water application throughout the field and is computed by,

$$\text{Du} = \frac{\text{Minimum depth}}{\text{Average depth}}$$

The minimum depth is calculated by taking the average of the lowest 1/4th of the can used in a particular test.

Determination of coefficient of variation

The coefficient of variation (CV) is the quotient between the standard deviation of the applied water depths (σ) and the average of water depth collected according to ASAE (1991) [2].

$$\text{CV} = \frac{\sigma}{\mu}$$

Where

σ = Standard deviation of the water depth of catch-cans

μ = Mean of all water depth of catch-cans, ml

Determination of mean application rate

Mean application rate is the depth of water applied by the rain pipe on the soil surface per unit time. It was estimated according to the following formula,

$$I = \frac{\sum X}{n \times t}$$

Where

I = application rate, mm/h

ΣX = Total depth of water collected in the catch cans (volume/area of can), mm
n = number of catch cans
t = time of operation, *h*

Determination of discharge and width coverage

Discharge of rain pipe was determined by collecting the water emitted by the rain pipe per meter length into a bucket in a given time. The observation of discharge was recorded twice for each operating pressure under 30m length of rain pipe. The maximum width wetted by the one rain pipe at different operating pressure measured manually using measuring Tap.

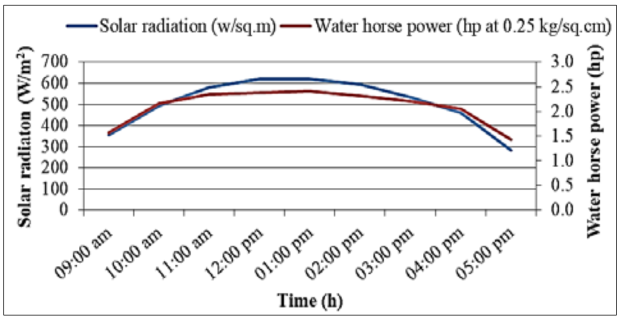
Results and Discussions

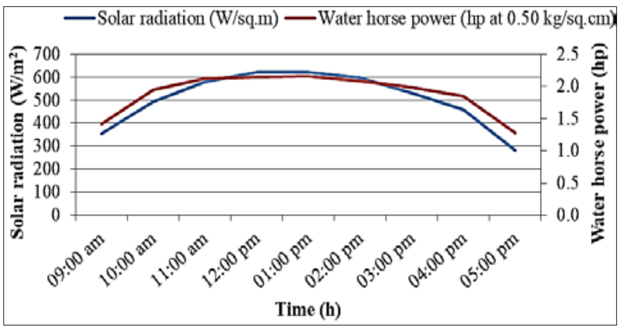
Diurnal variation of discharge with respect to solar radiation and operating pressure

The diurnal variation of discharge with respect to solar radiation at different operating pressure in a day was measured during the November-2019 to March-2020. Results indicated that as average solar radiation increases till 01:00 pm and then gradually it decreases. The same pattern was also observed for the discharge at different operating pressure. The solar radiation ranges from 458.70 W/m^2 to 621.26 W/m^2 during 10:00 am to 04:00 pm and maximum solar radiation received at 01:00 pm. The average discharge also ranges from 5.12 to 6.01, 4.61 to 5.41 and 4.19 to 4.92 lps at operating pressure 0.25 kg/cm^2, 0.5 kg/cm^2 and 0.75 kg/cm^2 respectively. Average discharge of 5.67, 5.10 and 4.64 lps was received from average solar radiation of 557.68 W/m^2 from 10:00 am to 04:00 pm at 0.25 kg/cm^2, 0.5 kg/cm^2 and 0.75 kg/cm^2 respectively. The results also indicated that, there is linear relationship between solar radiation and discharge of solar pump at particular operating pressure but the discharge is decreased as pressure increased due to increase in head.

Diurnal variation of water horse power with respect to solar radiation and operating pressure

The diurnal variation of water horse power with respect to solar radiation at different operating pressure in a day was measured during the November-2019 to March-2020.Average water horse power during November-2019 to March-2020with respect to solar radiation at different operating pressure in a day is presented in Figure 1.





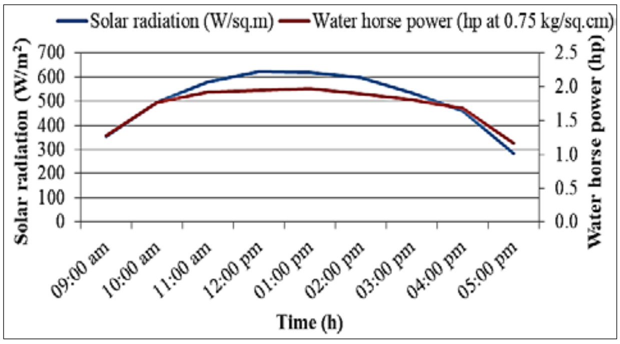


Fig 1: Variation of water horse power with respect to solar radiation and pressure during November 2019 to March 2020

Results indicated that as average solar radiation of November-2019 to March-2020 increased till 01:00 pm and then gradually it decreased. The same trend was also observed for the water horse power at different operating pressure. The solar radiation ranges from 458.70 W/m^2 to 621.26 W/m^2 during 10:00 am to 04:00 pm and maximum solar radiation was received at 1:00 pm.

The average water horse power also ranges from 2.05 to 2.40, 1.84 to 2.16 and 1.68 to 1.97hp at operating pressure 0.25 kg/cm^2, 0.5 kg/cm^2 and 0.75 kg/cm^2 respectively, from 10:00 am to 04:00 pm (Figure 1). Average water horse power of 2.27, 2.04 and 1.86 hp was received from average solar radiation of 557.68 W/m^2 from 10:00 am to 4:00 pm at 0.25 kg/cm^2, 0.5 kg/cm^2 and 0.75 kg/cm^2 respectively. The results also indicated that, there is linear relationship between solar radiation and water horse power of solar pump at particular operating pressure but the water horse power is decreased as pressure increased due to increase in head.

The values of uniformity coefficient, distribution uniformity, coefficient of variation and mean application rate resulted from testing at different operating pressures under 30m length and 4m spacing of rain pipe (Table 1).

Table 1: The effects of different operating pressure on CU, DU, CV and MAR for 30m length and 4m spacing of rain pipe

Operating pressure (kg/cm^2)	Uniformity coefficient (%)	Distribution uniformity (%)	CV (%)	Mean application rate (cm/h)
0.25	75.04	68.17	29.01	8.20
0.50	81.26	72.49	22.06	11.58
0.75	83.63	75.08	19.80	12.47

Effect of operating pressure on uniformity coefficient (CU) of rain pipe irrigation

Effect of various operating pressure on uniformity coefficient of rain pipe depicted in Figure 2. Results revealed that the value of uniformity coefficient was increased as operating pressure increased. The highest value of uniformity coefficient 83.63% was obtained at operating pressure of 0.75 kg/cm^2 and lowest value of uniformity coefficient 75.04% was obtained at operating pressure of 0.25 kg/cm^2.

Effect of operating pressure on distribution uniformity (DU) of rain pipe irrigation

Results indicated that the highest value of distribution uniformity 75.08% was attained at operating pressure 0.75 kg/cm^2 and lowest value of distribution uniformity 68.17% was attained at operating pressure 0.25 kg/cm^2 (Figure 3). It was observed that the value of distribution uniformity was increased as operating pressure increased.

Correlation coefficient

A regress equation about the uniformity coefficient and

distribution uniformity was built by using the coefficient of variation analysis for 30m length and 4m spacing of rain pipe and presented in Figure 4. It was observed that uniformity coefficient was consistently higher than distribution uniformity and both are inversely related to coefficient of variation. This result is found to be on one line with the finding obtained by Keller and Bliesner (2000) [11].
The maximum value of CV (29.01%) was attained at operating pressure of 0.25 kg/cm^2 and the minimum value (19.80%) was attained at operating pressure of 0.75 kg/cm^2. It was observed that value of CV decreased, if the operating pressure increased. To obtained better performance of the rain pipe irrigation system, CV must be lower. The relationship between CU, DU and CV is presented in Figure 4.

Effect of operating pressure on rain pipe irrigation mean application rate
The maximum value of mean application rate 12.47 cm/h was attained at operating pressure of 0.75 kg/cm^2 and least value of mean application rate 8.20 cm/h was attained at operating pressure 0.25 kg/cm^2 (Figure 5). It was observed that the value of mean application rate was increased as operating pressure increased for 30m length spaced at 4m spacing and vice versa.

Discharge per meter of rain pipe
The discharge per meter length of rain pipe and width covered by one rain pipe under different operating pressure is presented in Figure 6 and Table 2. Highest value of 200 LPH discharge per meter of rain pipe was measured at pressure of 0.75 kg/cm^{2}and lowest value of 126 LPH discharge per meter of rain pipe was measured at pressure of 0.25 kg/cm^2. It was also noticed that the value of discharge per meter of rain pipe was increased as pressure increased for 30m length and 4m spacing of rain pipe.

Table 2: Discharge per meter of rain pipe and width coverage by one pipe at various operating pressures

Operating pressure (kg/cm^2)	Discharge per meter of rain pipe (LPH)	Width coverage by one rain pipe (m)
0.25	126	4.5
0.50	160	6.5
0.75	200	8.1

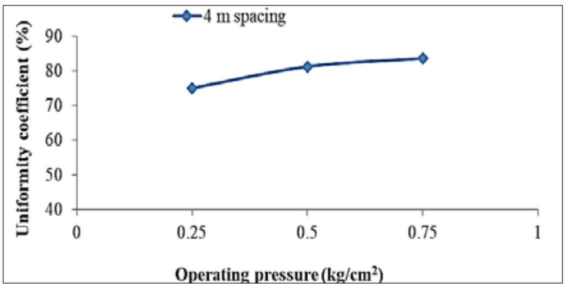


Fig 2: Response of operating pressure on uniformity coefficient of rain pipe

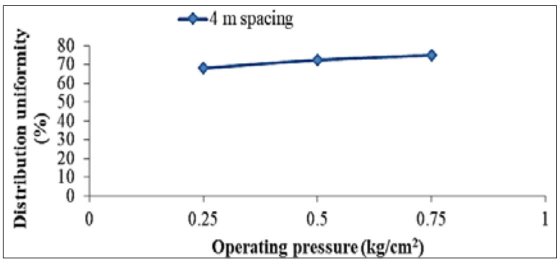


Fig 3: Response of operating pressure on distribution uniformity of rain pipe

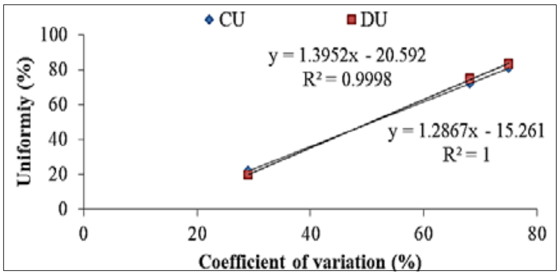


Fig 4: Relationship between CU and DU with CV of rain pipe

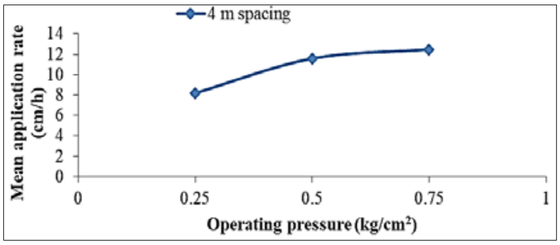


Fig 5: Mean application rate of rain pipe for different operating pressure

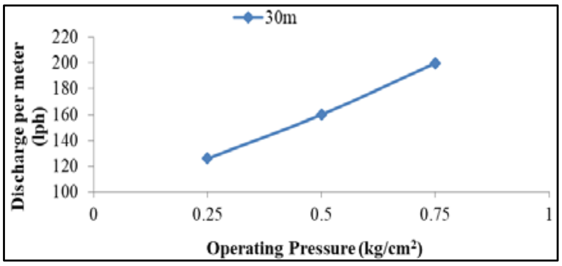


Fig 6: Discharge per meter of rain pipe at different operating pressure

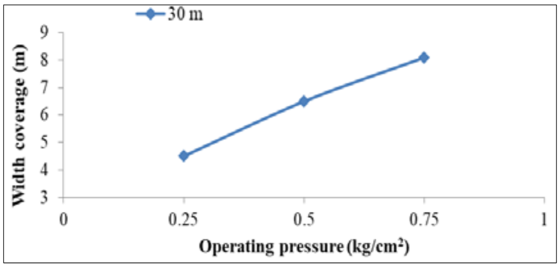


Fig 7: Width coverage by one rain pipe at different operating pressure

Width coverage
The highest width of 8.1m covered by one rain pipe was observed at operating pressure of 0.75 kg/cm^{2}and lowest width of 4.5m covered by one rain pipe was observed under operating pressure of 0.25 kg/cm^2. It was also noticed that width covered by one rain pipe was increased as pressure increased for 30m length and 4m spacing of rain pipe.

Conclusions
The average solar radiation ranged from 458.70 W/m^2 to 621.26 W/m^2 during 10:00 am to 4:00 pm and average maximum solar radiation 621.26 W/m^2 was received at 1:00 pm during November-2019 to March-2020. The average discharge of solar photovoltaic system ranged from 5.12 to 6.01, 4.61 to 5.41 and 4.19 to 4.92LPS at operating pressure of 0.25, 0.50 and 0.75 kg/cm^2 during 10:00 am to 4:00 pm. The average water horse power of solar photovoltaic pump ranged from 2.05 to 2.40 hp, 1.84 to 2.16 hp and 1.68 to 1.97

hp at operating pressure of 0.25, 0.50 and 0.75 kg/cm^2 during 10:00 am to 4:00 pm. Highest value of uniformity coefficient, distribution uniformity and mean application rate was attained at pressure 0.75 kg/cm^{2}for 30m length of rain pipe spaced at 4m spacing. Result shows that the uniformity coefficient, distribution uniformity and mean application rate is increased as increased the operating pressure and the coefficient of variation is increased as decreased the pressure. In order to obtain better uniformity of rain pipe irrigation system, it should operate at 0.75 kg/cm^2 operating pressure.

References

1. Arya CK, Purohit Dashora RC, Singh LK, Kothari M. Performance Evaluation of Drip Irrigation Systems. International Journal of Current Microbiology and Applied Sciences 2017;6(4):2287-2292.
2. ASAE. Design and Installation of Micro Irrigation Systems, ASAE Engineering Practice ASAE, USA 1991, P4051.
3. Bhattacharya AK. Integrated Water Management. Chapter 1 2007, P07-08.
4. Chistiansen JE. Irrigation by sprinkling. California Agriculture Experiment Station Bulletin 670, Berkely 1942, P124.
5. Cobo MT, Poyato EC, Montesinos P, Diaz JA. New model for sustainable management of pressurized irrigation networks - Application to Bembezar MD irrigation district (Spain), Science of the Total Environment 2014;8:473–474.
6. Dechmi F, Playan E, Cavero Faci JM, Martinez-Cob A. Wind effects on solid set sprinkler irrigation depth and yield of maize (*Zea mays*). Irrigation Sci 2003;22:67-77.
7. Eisa HG, Maroufpoor, Aslan Faryabi. Evaluation of Uniformity Coefficients for Sprinkler Irrigation Systems under Different Field Conditions in Kurdistan Province (Northwest of Iran). Journal of Soil and Water Resources 2010;4:139–145.
8. Elliott RE, Nelson JD, Loftis JC, Hart WE. Comparison of sprinkler uniformity models. Journal of Irrigation and Drainage Engineering. ASCE 1980;106:321-330.
9. Haman DZ, Smajstrla AG, Pitts DJ. Uniformity of Sprinkler and Micro-irrigation Systems for Nurseries, The institute of food and agriculture science 2003.
10. Karmeli D. Estimating sprinkler distribution pattern using linear regression. Trans. ASAE 1978;21:682-686.
11. Keller J, Bliesner RD. Sprinkler and Trickle Irrigation. The Blackburn Press, Caldwell 2000, P652.
12. Length F. Evaluation model development for sprinkler irrigation uniformity based on catch-can data. African Journal of Biotechnology 2011, P14796–14802.
13. Li J. Modeling crop yield as affected by uniformity of sprinkler irrigation system. Agric. Water Manage 1998;38:135-146.
14. Li J, Rao M. Sprinkler water distributions as affected by winter wheat canopy. Irrigation Science 2000;20:29-35.
15. Priyanka Raghavendra V, Palled V, Veerangouda M. Performance evaluation of solar water pumping system. International Journal of Current Microbiology and Applied Science 2018;7(5):133-142.
16. Qazi. Systematic Geography of Jammu and Kashmir. 2010, Chapter 1, P3-4.
17. Foster R, Cota A. Solar water pumping advances and comparative economics. Energy Procedia 2014;57:1431-1436.
18. Salmeron M, Urrego YF, Isla R, Cavero J. Effect of non-uniform sprinkler irrigation and plant density on simulated maize yield. Journal of Agricultural Water Management 2012;113:1–9.
19. Sourell EP. Performance of Rotating Spray Plate Sprinklers in Indoor Experiments, Journal of Irrigation and Drainage Engineering 2003, P376–380.