

DESIGN OF SEMI-PERMANENT SPRINKLER IRRIGATION SYSTEM AND ITS PERFORMANCE EVALUATION

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B. Tech. (Agril. Engg.)

**MASTER OF TECHNOLOGY
IN
AGRICULTURAL ENGINEERING
(SOIL AND WATER ENGINEERING)**



**DEPARTMENT OF SOIL AND WATER ENGINEERING
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DESIGN OF SEMI-PERMANENT SPRINKLER IRRIGATION SYSTEM AND ITS PERFORMANCE EVALUATION

BY

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B. Tech. (Agril. Engg.)

**THESIS SUBMITTED TO THE
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2011

DECLARATION

I, **G.V. RAMANA REDDY**, hereby declare that the thesis entitled **“DESIGN OF SEMI-PERMANENT SPRINKLER IRRIGATION SYSTEM AND ITS PERFORMANCE EVALUATION”** submitted to the **Acharya N. G. Ranga Agricultural University** for the degree of **Master of Technology in Agriculture** in the major field of **Soil and Water Engineering** is the result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

Place:

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Date:

I.D. No. BEM-07-002

C E R T I F I C A T E

Mr. G.V. Ramana Reddy has satisfactorily prosecuted the course of research and that the thesis entitled **“DESIGN OF SEMI-PERMANENT SPRINKLER IRRIGATION SYSTEM AND ITS PERFORMANCE EVALUATION”** submitted, is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part there of has been previously submitted by him for a degree of any University.

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C E R T I F I C A T E

This is to certify that the thesis entitled “**DESIGN OF SEMI-PERMANENT SPRINKLER IRRIGATION SYSTEM AND ITS PERFORMANCE EVALUATION**” submitted in partial fulfillment of the requirements for the degree of **Master of Technology in Agricultural Engineering** in the major field of **Soil and Water Engineering** of the Acharya N. G. Ranga Agricultural University, Hyderabad is a record of the bonafide original research work carried out by **Mr. G.V. Ramana Reddy** under our guidance and supervision.

No part of the thesis has been submitted for any other degree or diploma. The published part and all assistance received during the course of the investigations have been duly acknowledged by the author of the thesis.

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ABBREVIATIONS

AFC	Annual Fixed Cost
B C ratio	Benefit cost ratio
BIS	Bureau of Indian Standards
Cm	Centimeter
CSS	Central sponsored scheme
CUC	Christiansen Uniformity Coefficient
Cu	Coefficient of uniformity
DI	Diameter of lateral
Ds	Diameter of sub main
D-W	Darcy Weisbach
FSPS	Fixed Spray plate Sprinklers
G.I	Galvanized Iron
ha	Hectare
HDPE	High density poly ethylene
I.D.	Internal Diameter
i	Interest rate
Kg/cm ²	Kilogram per square centimeter
LAI	Leaf area index
lps	Liter per second
m	Meter

mm	millimeter
M & E	Monitoring and Evaluation
MGNREGS	Mahatma Gandhi National Rural Employment Guarantee Scheme
mm/hr	Millimeter per hour
m/s	Meter per second
NCPAH	National Committee on Plasticulture Applications in Horticulture
O&M	Operation and Maintenance
PVC _b	Poly vinyl chloride pipe buried
QAC	Quick Action Coupler
Re	Reynolds number
RSPS _s	Rotating spray Plate sprinklers
Rs/-	Rupees
SPSIS	Semi permanent sprinkler irrigation systems
TAC	Total Annual cost
Ø	Diameter

ABSTRACT

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In India, National and State Governments have been spending crores of rupees to promote the concept of Micro-irrigation systems among the farmers and to take up these installations. But the concept of Micro-irrigation especially sprinkler irrigation is not being much popularized due to improper designs by the respective subsidy program implementing agencies, lack of awareness among the farmers about the system operation, maintenance, lack of agronomical support & after sale services to the systems installed by the micro-irrigation companies. Several case studies about the performance of conventional portable sprinkler irrigation systems have revealed that a maximum of 8 to 10% of the supplied units under government subsidy programs are only performing well and the rest are being operated below the satisfactory levels.

At the time of present study, during interaction with the farmers, it was expressed that better performing with less cumbersome and cost effective sprinkler irrigation system is badly needed for them to overcome the present problems of non uniform spray covering less area of wetting etc. It automatically shows that the farmers are fully realized the importance of an efficient semi permanent sprinkler irrigation system in comparison with flood irrigation and conventional sprinkler systems.

Design of semi-permanent sprinkler irrigation system was felt very much essential for the farming community to reduce their overall investment costs towards irrigation in addition to overcome the labor problems for some extent. So far, attempts made for improvement of designs on this research need was very limited. Hence, an attempt was made to bring a reasonably good and cost effective semi-permanent sprinkler irrigation system design in the present study.

The present study mainly focused on the design of semi-permanent sprinkler irrigation system with some improvements over the existing portable and SPSI systems operated by the farmers of Andhra Pradesh. The performance of the designed semi-permanent sprinkler irrigation system was evaluated at field level and the results were compared with the performance of previously existing such systems in addition to several conventional portable sprinkler irrigation systems.

The total system head loss with the telescopic sub main (75mm Ø for 36m, 63mm for 60m and 40 mm Ø for 24m), telescopic laterals (32 mm for 24m and 25 mm Ø for 12 m) and risers of 25mm Ø for 1.5 m long was observed to be 3.99m. where as the telescopic lateral was extended to 48m (32 mm Ø for 24m and 25 mm Ø for 24m, keeping the riser dimensions as same), the total system head loss was found to be 4.97m. The total system head losses in above cases were found to be within the permissible limits of 20% allowable pressure variation within the system from the operating pressure of 25m head.

The performance of sprinkler irrigation system developed at present and the conventional system as control was evaluated based on Christiansen Uniformity coefficients (CUCs) by using Catch Can method. It was observed that the C_u of developed semi-permanent sprinkler irrigation system was 91.1% when system operating pressure was 2.5 kg/cm^2 with rotating impact sprinklers at a discharge of 0.67 lps.

The total annual cost for both portable SI and SPSI systems were estimated and found that there was a cost reduction of 60.64% in SPSI system (Rs. 7,955.00) over the portable SI system (Rs. 20,213.00). Taking these total annual costs of both the systems into the account and field data collected like crop yield and cost of cultivation from the farmers the benefit cost ratio was calculated. It was observed that the SPSI system designed was more beneficial with B C ratio of 1:1.98 over the portable SI system (B C ratio of 1:1.07). Therefore, the SPSI system

designed in the present study was found cost effective over the portable SI system for the farmers.

Regarding the study about the performance comparison of developed system with already available semi-permanent sprinkler irrigation and portable conventional sprinkler irrigation systems which are in practice by the farmers was conducted in Ananthapur, Kadapa and Nalgonda Districts. It was observed that almost all the systems were operating at a low pressure (i.e., pressure ranges from 0.9 to 1.2 kg/cm²), due to which the overlapping of sprinklers and spray pattern was non uniform.

Finally, it can be concluded that the technical feasibility study for successful operation of sprinkler irrigation systems, either portable or semi-permanent/permanent is highly essential before taking up the installation. This research work will certainly be useful as a prerequisite for the implementing agency/organization before deciding the type of sprinkler irrigation system in the farmers' fields.



Chapter-I

Introduction

Chapter - I

INTRODUCTION

India accounts for 17 percent of the world's human population and nearly 30 percent of the cattle with only 2.4 percent of the land and 4 percent of water resources. Even if the full irrigation potential is exploited, about 50 percent of the country's cultivated area will remain un-irrigated, particularly with current level of irrigation efficiency. The availability of water per person per year is about 2200 m³ for India and about 800 m³ for southern states (1400 m³ A.P.). The share of water for agriculture would reduce further with increasing demand from other sectors.

The productivity in rain fed and irrigated areas will be 1.5 tonne/hectare and 4.0 tonne/ha respectively. This scenario can be changed by adoption of water management practices in surface irrigation methods and introducing drip and sprinkler irrigation as recommended by task force committee report on Micro Irrigation in 2004. According to the report of the task force committee report, the potential for coverage under drip and sprinkler irrigation is estimated to be about 27 million hectares and 42.5 million hectares, respectively.

To meet the growing demand for food in accordance with the population growth year by year. The production of food grains has to be raised many folds with increase in productivity by enhancing the water use efficiency with effective irrigation methods.

Micro Irrigation was introduced in India from 1970's onward to overcome many losses observed in conventional practice of flood irrigation. Out of all types of micro irrigation systems, sprinkler irrigation is having more scope in India.

The kind of sprinkler irrigation followed by the farmers, mostly is of portable type among several types like portable, semi-portable, semi-permanent and permanent etc. The main reason for practice of portable type sprinkler system by the farmers in India is that the manufacturers prefer portable type systems due to inadequate technical competence of the field staff to find solutions to different situations. The manufacturers supply the components of portable type system as a unit according to the

recommendations of National Committee on Plasticulture Applications in Horticulture (NCPAH) and Central Sponsored Schemes (CSS) guidelines. Such sprinkler unit/set per one hectare consists of five no's. of sprinkler heads with riser & foot batten assembly, 25 numbers of High Density Poly Ethylene (HDPE) pipes, one pump connector, one bend, one tee and 2 numbers of cap ends. In each shift, irrigation is given to a depth of 2 to 2.5 cm at the rate of flow of 0.5 lps from sprinkler head and time allowed for each shift is 96 to 120 minutes, respectively to sprinkler placed at spacing of 12 X 12 m. To irrigate one hectare of land requires 14 numbers of shifts in each shift an area of 720 m² is irrigated @ 144 m²/sprinkler head. Studies of different Monitoring and Evaluation (M&E) agencies revealed that the conventional portable sprinkler irrigation system is too laborious and causes crop damage due to movement of pipes. Farmers are also unable to utilize the maximum extent of limited available power supply because of wastage of time in shifting.

Due to inadequate technical competence of manufacturers or suppliers to offer best type of systems according to different field conditions, just they are supplying the components of portable sprinkler irrigation system as a unit under government subsidy schemes. In many of the situations, the existing portable sprinkler irrigation systems are operating at low pressure than the manufacturers recommended operating pressure lead to unsatisfactory performance in the field with low coefficient of distribution, coverage uniformity, more consumption of time & electricity for irrigating an unit area and more drudgery for more number of shifts required with portable systems per covering an unit area.

During interaction with the farmers, it was expressed that a better performing with less cumbersome and cost effective sprinkler irrigation system is badly needed for them to overcome these present problems encountered. It is observed that the farmers are fully realized the importance of an efficient semi permanent sprinkler irrigation system in comparison with flood irrigation and conventional sprinkler systems. During the experimentations, it was realized and received the feedback from the farmers that they have noticed better crop yields even with system failures and drawbacks.

To overcome all the disadvantages of portable sprinkler system, the semi-permanent sprinkler irrigation practice is felt as a better alternative when compared to conventional system. It appears that very little research work has been done so far on the development of alternate systems. Hence, it was felt necessary to work further on the research problem titled "Design of Semi-permanent Sprinkler Irrigation System and its Performance evaluation" to fulfill the following objectives.

1. Design of low cost hydraulically efficient semi-permanent sprinkler irrigation system.
2. Study of hydraulic performance of the sprinkler irrigation system designed.

Performance comparison of the sprinkler irrigation system designed with conventional portable system.



Chapter-II

Review of Literature

Chapter - II

REVIEW OF LITERATURE

The following literature has been reviewed about different types of sprinkler irrigation systems, and the performance evaluations with respect to several design procedures adopted for installation. Most of the scientists have conducted research on crop yield response to different methods of pressurized irrigation systems like sprinkler, drip and micro sprinklers. It was observed that only limited research was available on hydraulic designs and performance, comparison of improved systems with conventional ones, which were practiced by the farmers at field level.

2.1. Hydraulic Design of Sprinkler Irrigation Systems

Romero *et al.* (2006) analyzed the annual water application costs per unit area (ha) and analyzed subunit of sprinkler irrigation systems designed with pipes of different materials. This study concluded that the permanent sprinkler system using PVC_b (buried), produced the lowest annual water application cost per unit area in comparison with other three surface solid-set systems. The parameters considered in this study are the total annual cost, water cost, energy and labour.

Valiantzas (2003a) developed a new simple equation, which is derived to solve explicitly the economic design problem of sub main lines (micro irrigation manifold and sprinkler irrigation sub mains) with pumping. The explicit economic design is demonstrated in two design examples. Comparisons with previous methods and numerical models indicated the good performance of the suggested solution.

Valiantzas (2003b) reported that the optimum hydraulic design problem was solved for micro irrigation sub main units of specified dimensions analytically. New algebraic equations were derived to calculate explicitly the optimum values of the design variables. The design variables were the lengths of two given pipe sizes for the laterals as well as the appropriate lengths of the available pipe sizes for the manifold. Tapered laterals and manifold were selected in such a way that the sum of the costs of the laterals and the manifold was minimized, while the hydraulic design criterion was ensured. The optimum design procedure was also applied in tapered sprinkler irrigation. The explicit optimum design solution was demonstrated in two cases studied in this experiment.

Mahar *et al.* (2001) developed a methodology to select a sprinkler lateral from different design alternatives for a duration shorter than its full life cycle. The selection was made by determining the time period up to which an alternative would be more economical than others. A procedure was developed for selecting a sprinkler lateral in the case of an owner wanting either to change the enterprise or to replace the system before the end of the life cycle.

Von Bernuth (1990) listed out the following advantages by insertion of the Blasius friction factor into the Darcy-Weisbach equation, which results in a combined equation.

1. It was is theoretically sound and dimensionally homogeneous. Both the Blasius and D-W equations had theoretical base.
2. It was very accurate for plastic pipe when Reynolds numbers were less than 100,000. The Reynolds number limit was non-restrictive for irrigation-system design using smaller than 80 mm.
3. It was conveniently written in readily available terms: flow rate, length, and diameter.
4. It could be easily corrected for viscosity changes directly.

Keller and Bliesner (1990) gave the formulae and tables to calculate the head loss due to friction in pipeline. The Hazen-Williams equation was used for aluminium pipe of sprinkler irrigation. The Darcy-Weisbach equation was used for polyethylene hose of trickle irrigation and IPS-PVC thermoplastic pipe of sprinkler and trickle irrigation. They also quoted two other equations, which were used for smooth plastic pipes of smaller diameter (less than 125 mm) and larger diameter (greater than 125 mm)

Von Bernuth and Wilson (1989) confirmed from their analysis of data collected on three small diameter plastic pipe sections that the Blasius equation was a very accurate predictor of the Darcy-Weisbach (D-W) friction factor when Reynolds numbers are less than 100,000. The two equations were readily combined into one that is dimensionally homogeneous and contains a viscosity term. It was conveniently written in flow rate, pipe diameter, and pipe length terms.

Scaloppi (1988) derived an adjusted F factor to compute pressure head loss in pipes having multiple, equally spaced outlets for any given distance from the first outlet to the beginning of the pipe. The proposed factor was dependent on the number of outlets and was expressed as a function of the Christian's F factor.

$$F = \frac{1}{m+1} + \frac{1}{2N} + \frac{(m-1)^{0.5}}{6N^2} \quad (2.1)$$

where, F = Christian's F factor,

m = velocity exponent in the formula used for friction loss computation and

N = the number of outlets

Jensen (1981) recommended Darcy-Weisbach formula to compute friction loss in pipes. It was mentioned that the sprinkler industry often uses Scobey's or Hazen-Williams formula for calculating the friction loss in pipes, since these equations uses a constant factor for each pipe material. Tables were needed for estimation of energy losses with the dimensionally consistent Darcy-Weisbach equation to encourage greater industry use.

Hazen-Williams and Darcy-Weisbach equations

By considering drip irrigation pipes hydraulically smooth, any of the several empirical equations were used to calculate head loss due to friction. The Darcy-Weisbach equation, begins with

$$h_f = \frac{fLV^2}{2gD} \quad (2.2)$$

where, h_f = head loss due to friction, m

f = dimensionless friction factor, dimensionless

L = length of pipe, m

V = velocity of water in pipe, m/s

D = diameter of the pipe, m

g = acceleration due to gravity, m/s^2

Since drip irrigation lateral lines were assumed to be hydraulically smooth and flow was fully turbulent, the Blasius empirical formula for turbulent flow in a smooth pipe can be substituted for f (Wu and Gitlin, 1974, Howell et al., 1981). The Blasius formula is

$$f = \frac{0.316}{R_e^{0.25}} \quad (2.3)$$

where, R_e = Reynolds number, dimensionless

Among all the equations, the Hazen-Williams formula was commonly and most frequently used (Keller and Karmeli, 1975; Jeppson, 1982). The Hazen-Williams formula for smooth pipe (using $C=150$) were shown as

$$\Delta H = 15.27 \frac{Q^{1.852}}{D^{4.871}} \Delta L \quad (2.4)$$

where, ΔH = energy drop by friction for a given pipe length(ΔL), m

Q = discharge rate, $l\ s^{-1}$

D = is the inside diameter (I.D.), cm

Because of its simplicity, the Hazen-Williams equation (Bezdek and Solomon, 1978) was widely used in the irrigation industry to calculate friction losses in irrigation pipes. This use had been extended to include plastic irrigation lateral lines, even though such lines generally had smaller diameters and lower flow rates than were usually encountered in other irrigation systems. Regarding trickle laterals, Keller and Karmeli (1974) noted that the Hazen-

Williams equation with a roughness coefficient of C as 150 was normally used for plastic pipe. Howell and Hiler (1974) gave an argument for using $C=130$. Bezdek and Solomon (1978) indicate that no matter what value of C was chosen for use in the Hazen-Williams equation, the Darcy-Weisbach equation was a more accurate basis for calculating head losses in the small diameter plastic tubing used for trickle laterals.

Watters and Keller (1978) and (1989) had shown that the Blasius equation worked well for small diameter plastic pipe when Reynolds number was less than 100,000. Design limitations on velocity in irrigation pipelines (1.5 m/sec) would limit Reynolds numbers to 100,000 for pipe 64 mm or smaller. When the velocity was at the design limit, the error for 102 mm pipe with Reynolds number of 157,400 would be -3.6% and for 152 mm pipe with Reynolds number of 236,100 the error would be -5.6%. Assuming that the design velocity limits were met the Blasius equation would yield reasonably accurate estimation of the friction factor for pipe smaller than 80 mm. The 100,000 Reynolds number limits should be adhered to for pipes larger than 80 mm.

Many practicing engineers hesitated to use the D-W equation and preferred simpler empirical equations not requiring calculation of the Reynolds number and reference to a table of viscosity values. However, failure to correct for viscosity differences could lead to significant error. For example, a 20 °C change in temperature would lead to 11% error in friction loss if viscosity changes were ignored. In spite of the accuracy disadvantages of empirical equations, engineers continued to use them.

In the past the incomplete knowledge of the flow velocity profile encouraged the empirical analysis of the friction factor measurements. Empirical relationships like Blasius, Hazen-Williams and Manning's equations (Kamand, 1988; von Bernuth and Wilson 1989) were developed. Some of these relationships characterized by a simple mathematical form, neglected the variability of the friction factor with the flow conditions and as a result they only allowed accurate head loss estimation for given ranges of velocity and pipe diameter.

2.2 Performance Evaluation of Sprinkler Irrigation Systems

Bhakar *et al.* (2008) evaluated the performance characteristics of micro-sprinkler was evaluated under various operating conditions in respect of pressure-discharge relationship and field performance in terms of uniformity coefficient, emission uniformity, and distribution uniformity. Suitable operating pressure ranging from 0.75 to 2.0 kg/cm² and spacing between micro-sprinklers 1.5 x 1.5 m, 2.25 x 2.25 m, 3.0 x 3.0 m and 3.75 x 3.75 m were tested for pressure discharge relationship as well as uniformity coefficient, emission uniformity and distribution uniformity under low wind speed condition. Pressure discharge relationship was developed in the form of power equation $Q = 44.45 P^{0.78}$. The emission uniformity was found to be more than 90%. The uniformity coefficient and distribution uniformity increased with increasing operating pressure and decreased with increase in micro-sprinkler spacing.

Based on operating conditions it was concluded that the micro-sprinkler should be operated at a pressure range of 1.5 to 2.0 kg/cm² and at a spacing of 1.5 x 1.5 m.

Kadam *et al.* (2006) studied the field performance of micro-sprinkler in terms of uniformity as influenced by the operating pressure and micro-sprinkler spacing was evaluated. Uniformity decreased with the increase the spacing from 1.5 X 1.5m to 3.75m X 3.75m. With increase in the operating head from 0.75 to 2.0 kg/cm², uniformity increased. For the rotating head micro-sprinkler, the spacing of 1.5m x1.5m may be used with operating head pressure of 1.0 kg/cm² and 2.25m X 2.2.5m for 2.0 kg/cm².

Faci *et al.* (2001) conducted a comparative study of two types of spray sprinklers. Rotating Spray Plate Sprinklers (RSPS_s) and Fixed Spray Plate Sprinklers (FSPS_s) were evaluated individually in open field conditions. The water distribution, wind drift, and evaporation losses during the evaluations were measured under low, medium, and high speed conditions, with three nozzle diameters and two nozzle heights above the soil surface. The uniformity FSPS_s were found to be more than 93% in all the cases. However, the RSPS could attain higher uniformity coefficient at higher spacing along the lateral.

Jiusheng Li *et al.* (1999) conducted a study on the effect of sprinkler uniformity on crop yield which was a concern for system designers because it was an important consideration in selection of target uniformity for conventional systems. However, there was few field data on this subject. Field experiments were therefore conducted to observe the spatial variations of water in the soil and to study the response of crop growth and yield to non uniform water application during the irrigation season of winter wheat in north China. Christiansen uniformity coefficients (CUC) were used in this article to quantify the uniformity of sprinkler water above and below canopy, soil water content, plant height, LAI, and crop yield. The results demonstrated that CUCs for water storage in the soil were always greater than 90% even though sprinkler uniformities varied from 57% to 89% during the irrigation season. Also, the uniformities of plant height, LAI, and crop yield were higher than those for water application and seem to be insensitive to spatial variation of applied water. The influence of sprinkler uniformity on crop yield was not as important as previous modeling. A reduced uniformity might not necessarily result in a lower yield.



Chapter-III

Materials and Methods

MATERIALS AND METHODS

This chapter deals with the methodology adopted and theoretical considerations made for achieving the objectives of the present study. The details of the design and methods adopted for performance evaluation of the SPSI system are described below:

3.1 Theoretical Considerations

Different formulae used for estimating the head losses due to friction for different discharge through the pipe network of sprinkler irrigation system were mentioned below.

3.1.1 Friction loss equation

In general, the friction drop equation for pipe flows was shown in simplified form as

$$\Delta H = kQ^m \Delta L \quad (3.1)$$

where, ΔH = the total energy drop of a pipe section, m

k = constant for a given pipe size and type of flow, dimensionless

Q = discharge rate, lps

ΔL = pipe section length, m

m = an exponent, dimensionless

Both the Hazen-Williams and Darcy-Weisbach equations were used in the formulation.

3.1.2. Hazen-Williams equation

Among all the equations, the Hazen-Williams formula was commonly and most frequently used (Keller and karmeli, 1975; Jeppson, 1982). The Hazen-Williams formula for smooth pipe ($C=150$) can be shown as

$$\Delta H = 15.27 \frac{Q^{1.852}}{D^{4.871}} \Delta L \quad (3.2)$$

where,

ΔH = energy drop by friction for a given pipe length (ΔL), m

Q = discharge rate, l s^{-1}

ΔL = length of pipe, m

D = inside diameter of the pipe, cm

The above equation modified into the following form was used in computation of frictional head loss

$$H_f = \frac{3152.7375 L Q^{1.852}}{C^{1.852} D^{4.871}} \quad (3.3)$$

where,

H_f = frictional head loss, m

L = length of pipe, m

Q = flow rate, l h^{-1}

D = internal diameter of pipe, mm

C = a constant having different values for different pipe materials and sizes (Hazen-Williams constant), dimensionless

For PVC pipes the following values of C were generally used

$C = 130$ ($D < 17$ mm)

$C = 140$ ($17 \geq D < 21$ mm)

$C = 150$ ($D > 21$ mm).

3.1.3. Darcy-Weisbach equation

Research workers have found Darcy-Weisbach formula more accurate, theoretically sound dimensionally correct among all other equations. The frictional head loss due to Darcy-Weisbach equation depends on the flow regime in the pipeline, which is characterised by the Reynolds number. The Darcy-Weisbach equation for frictional head loss was given by:

$$H_f = \frac{f L V^2}{2g D} \quad (3.4)$$

where, D = internal diameter of pipe, m

V = velocity of flow, m s^{-1}

g = acceleration due to gravity, m s^{-2}

f = Darcy's frictional factor, dimensionless

H_f and L are equal to ΔH and ΔL as defined earlier

Considering discharge in place of velocity and taking $g = 9.81 \text{ m s}^{-2}$ in the above Eq. 3.4, we get,

$$H_f = 6.3755f L Q^2 D^{-5} \quad (3.5)$$

where, H_f , L , Q and D are as defined in Eq. 3.3.

The friction loss coefficient 'f' depends upon Reynolds number and the relative roughness of the pipe. Drip irrigation laterals are generally made of smooth materials. Flow in laterals is generally turbulent at its upstream end and flow becomes laminar at the downstream reach. The flow regime is characterised by the Reynolds number (R_e) and for cylindrical flow path is given by

$$R_e = \frac{4Q}{k \eta \pi D} \quad (3.6)$$

where,

Q = flow rate in pipe, l h^{-1}

k = a constant equal to 3600

η = kinematic viscosity of water, $\text{m}^2 \text{s}^{-1}$

D = internal diameter of pipe, mm

Another form of the above Eq. 3.6 is

$$R_e = \frac{1.111 \times 10^{-3} Q}{\eta \pi D} \quad (3.7)$$

Relationship between temperature and kinematic viscosity can be expressed as

$$\eta_T = 0.98^{(T-20)} \eta_{20} \quad (3.8)$$

where,

η_T = kinematic viscosity of water at temperature, T °C

T = temperature of water in °C

η_{20} = kinematic viscosity of water at 20 °C ($1.003 \times 10^{-6} \text{ m}^2 \text{s}^{-1}$)

The friction loss coefficient for different flow regime was given by:

For laminar flow,

$$f = 64 R_e^{-1.0} \quad (R_e < 4000) \quad (3.9)$$

For turbulent flow, the Blasius equation was:

$$f = 0.316R_e^{-0.25} \quad (4,000 > R_e < 1,00,000) \quad (3.10)$$

For fully turbulent flow,

$$f = 0.130R_e^{-0.172} \quad (R_e > 1,00,000) \quad (3.11)$$

Substituting the value of R_e from Eq. 3.7 into Eq. 3.9 and then substituting the value of 'f' into Eq. 3.5 and by taking $g = 9.81 \text{ m s}^{-2}$,

$$\text{Than, } H_f = 1.1537 \times 10^6 \eta L Q D^{-4} \quad (3.12)$$

Similarly substituting the value R_e from Eq. 3.7 into Eq. 3.10 and then substituting the value of 'f' into Eq. 3.5 resulted in

$$H_f = 14.69 \eta^{0.25} L Q^{1.75} D^{-4.75} \quad (3.13)$$

and also by similar substitution of the value of R_e from Eq. 3.7 into Eq. 3.11 and then substituting the value of 'f' into Eq. 3.5 resulted in

$$H_f = 3.2513 \eta^{0.172} L Q^{1.828} D^{-4.828} \quad (3.14)$$

The values of 'k' and 'm' in Eq. 3.1 for different flow regimes were given in the following table.

Equation	Flow regime	k	m
	Laminar	$1.1537 \times 10^6 \eta L D^{-4}$	1.0
Darcy-Weisbach	Turbulent	$14.69 \eta^{0.172} L D^{-4.828}$	1.75
	Fully turbulent	$3.2513 \eta^{0.172} L D^{-4.828}$	1.828
Hazen-Williams		$\frac{3152.7375 L}{C^{1.852} D^{4.871}}$	1.852

The symbols L, Q, D, η and C carry same meaning as specified in earlier equations

3.2 Components of sprinkler irrigation system

Sprinkler system usually consists of the following components

- i. A pump unit
- ii. Tubing's - main/sub mains and laterals
- iii. Couplers

- iv. Sprinkler head
- v. Other accessories such as valves, bends, plugs and risers.

3.3. General classification of different types of sprinkler systems

Sprinkler systems were classified into the following two major types on the basis of the arrangement for spraying irrigation water.

1. Rotating head or revolving sprinkler system.
2. Perforated pipe system.

Based on the portability, sprinkler systems were classified into the following types.

1. Portable system

A portable system has portable main lines, laterals and pumping plant. The components of a portable system.

2. Semi-portable system

A semi portable system is similar to a portable system except that the location of water source and pumping plant is fixed.

3. Semi-permanent system

A semi permanent system has permanent lateral lines, permanent main lines and sub mains and a stationery water source and pumping plant, only sprinklers are shiftable.

4. Permanent system

A fully permanent system consists of permanently laid mains, submains laterals, sprinklers and a stationery water source and pumping plant.

3.4. General Rules for the Design of Sprinkler Irrigation System

- i. Main should be laid up and down hill

- ii. Lateral should be laid across the slope or nearly on the contour
- iii. For multiple lateral operations, lateral pipe sizes should not be more than two diameters
- iv. Water supply source should be nearest to the center of the area
- v. Layout should facilitate and minimize lateral movement during the season
- vi. Booster pump should be considered where small portion of field would require high pressure at the pump
- vii. Layout should be modified to apply different rates and amounts of water where soils are greatly different in the design area.

3.5. Selection of the Most Appropriate Sprinkler Systems

While selecting a sprinkler system, the most important physical parameters to be considered were:

1. The crop or crops to be cultivated.
2. The shape and size (acres) of the field.
3. The topography of the field.
4. The amount of time and labor required to operate the system.

3.6 Selection of Sprinkler System Capacity

A sprinkler system must be designed to apply water uniformly without runoff or erosion. The application rate of the sprinkler system must be matched to the infiltration rate of the most restrictive soil in the field. If the application rate exceeds the soil intake rate, the water will flow as runoff over the field or relocate within the field resulting in over and under watered areas.

The sprinkler system capacity defined flow rate needed to adequately irrigate an area and expressed in liters per minute per acre. The system capacity depends upon the following parameters:

1. Peak crop water requirements during the growing season
2. Effective crop rooting depth
3. Texture and infiltration rate of the soil
4. The available water holding capacity of the soil
5. Pumping capacity of the well or wells (if wells are the water source).

3.7. Semi-Permanent Sprinkler Irrigation System

If the number of laterals was increased so that the field was fully covered by laterals and each lateral fitted with sprinklers, it is known as a solid-Set System. There was an intermediate stage where only the sprinklers were moved, it is termed as semi- permanent sprinkler system.

There are many variations of these systems. Three common examples are

1. Fixed laterals with sprinklers being moved from one lateral to the next one. The wetted strip is parallel to the laterals.
2. Fixed laterals with sprinklers being moved along the laterals (one sprinkler per lateral). The wetted strip is perpendicular to the laterals.
3. A flexible lateral with one sprinkler at the end towed by hand, back towards the mainline. The wetted strip is parallel to the mainline (or to a secondary line).

Among the three examples, second one is the most economical in design and as the lateral feeds only one sprinkler at a time.

3.8 Design of Semi Permanent Sprinkler Irrigation System (SPSIS)

As the Government is investing crores of rupees in the form of releasing subsidies to the farmers for the adaption of the systems, the efficient design should meet the following requirements for the successful implementation as well as for the farmers' satisfaction.

1. Should be hydraulically efficient
2. Should be economically viable
3. Should last for long time.
4. Should be operational for low Operation and Maintenance costs.
5. Should be easily operated by farmers.

Hydraulically efficient & cost effective semi-permanent sprinkler system has been designed with generally available BIS certified impact sprinklers of 0.5 to 0.7 lps discharge at an operating pressure of 2.0 to 2.5 kg/cm² and different sizes & strengths of PVC pipes of reputed makes. The

designed SPSI system was introduced to overcome the disadvantages of the conventional portable sprinkler systems with the following criteria.

1. 32 mm x 8 kg/cm² and 25 mm x 10 kg/cm² diameter PVC pipes were used as the laterals
2. Laterals were laid on both sides of the submain
3. Maximum length of lateral pipe was limited to 36 m to maintain pressure variation within the desired limit.
4. Only one sprinkler head of 0.5 lps discharge was operated at a time on one lateral.
5. PVC pipes of 75 mm x 4 kg/cm², 63 mm x 4 kg/cm² and 40 mm x 6 kg/cm² size with telescopic design were used for sub mains.
6. BIS (Bureau of Indian Standards) certified sprinklers with flow rate of 0.5 to 0.7 lps were used
7. For one-hectare area total 70 risers were required to cover entire field.
8. A suitable pump set capable of giving required head and discharge to run 10 number of sprinkler heads at a time per shift was selected.
9. As per the layout discussed below the SPSI system was installed and tested the performance.

3.8.1 Design procedure and cost estimation

A software called Hydrocalc of Netafim Irrigation Pvt. Limited, was used for calculating the pressure heads at different nodal points based on the Darcy - Weisbach equation for the assumptions made to design a hydraulically efficient SPSI system.

To bring hydraulically efficient SPSI system, all losses (i.e., in submains, laterals, risers and fittings) put together should not exceed 20% of the recommended operating pressure head. The calculated values of head losses were tabulated. The procedure of calculations were shown in Appendix - I. The cost of the system was estimated for two options, 1) When the water source exists just outside and near the field boundary and 2) when the water source exists at the centre of the field and given in Table 3.1 and 3.2

Table 3.1 Cost of the SPSI system estimated for 1 ha. (water source just outside the field)

S.No	Item description	Quantity	Unit Price, (Rs)	Total cost, (Rs).
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1	PVC pipe-25mmX10 Kg/cm ²	360 m	13.95	5022.00
2	PVC pipe-32mmX8 kg/cm ²	504m	17.45	8794.80
3	PVC pipe-40mmX6 Kg/cm ²	30 m	20.40	612.00
4	PVC pipe-63mmX4 Kg/cm ²	66 m	39.00	2574.00
5	PVC pipe-75mmX4 Kg/cm ²	42 m	46.59	1956.78
6	PVC R/Tee -32mmX25mm-6PN	50 no	4.80	240.00
7	PVC Elbo -25mm-6PN	20 no	2.75	55.00
8	PVC ball valve-25mm-6PN	70 no	42.00	2940.00
S.No	Item description	Quantity	Unit Price, (Rs)	Total cost, (Rs).
9	Sprinkler nozzle-0.5 lps	10 no	200	2000.00
10	PVC R/Tee-75mmX32mm-6PN	6 no	34	204.00
11	PVC R/Tee-63mmX32mm-6PN	10 no	30	300.00
12	PVC R/Tee-40mmX32mm-6PN	4 no	25	100.00
13	PVC FTA-25mm-6PN	70 no	2	140.00
14	PCN -75mm	1 no	186.15	186.15
15	Solvent cement	2 Lt	154	308.00
16	Miscellaneous	LS		2067.27
Total				27,500.00

Table 3.2 Cost of the SPSI system estimated for 1 ha. (water source at centre of the field)

S.No.	Item description	Quantity	Unit Price (Rs)	Total Cost, (Rs)
1.	PVC Pipe-25mm X 10Kg/cm ²	360m	13.95	5022.00
2.	PVC Pipe-32mm X 8Kg/cm ²	504m	17.45	8794.80
3.	PVC Pipe-40mm X 6Kg/cm ²	54m	20.40	1101.60
4.	PVC Pipe-63mm X 4Kg/cm ²	66m	39.00	2574.00
5.	PVC Pipe-75mm X 4Kg/cm ²	30m	46.59	1397.70
6.	PVC R/Tee-32mm X 25mm-6PN	50 No.	4.80	240.00
7.	PVC Elbo-25mm -6PN	20 No.	2.75	55.00
8.	PVC Ball Valve-25mm-6PN	70 No.	42.00	2940.00
9.	PVC FTA-25mm-6PN	70 No.	2.00	140.00
10.	Sprinkler nozzle-0.5 lps	10 No.	200.00	2000.00
11.	PVC R/Tee-63mm X 32mm 6PN	8 No.	30.00	240.00
12.	PVC R/Tee-40mm X32 mm 6PN	12 No.	25.00	300.00
13.	PCN-75mm	01 No.	186.15	186.15
14.	Solvent cement	2 Lt	154.00	308.00
15.	Miscellaneous	LS		1700.75
			Total	27,000.00

The total head required for a pump set was calculated by considering the friction head losses in entire pipe network (submain, lateral, riser & fittings) and the procedure for calculation was shown in Appendix – II.

A total discharge of 5 lps was selected to run 10 sprinklers at a time, at the rate of 0.5 lps per sprinkler.

As per the required head and discharge, an open well submersible pump set of 5hp was selected from CRI company make.

3.9 Layout of SPSI System

A plot size of 120 m x 84 m with a water source just outside of the field from one end was taken as one option for design purpose as shown in Fig 3.1. A telescopic sub-main line with different sizes & strengths of pipes i.e., 75mm x 4Kg/cm², 63 mm x 4 kg/cm² and 40 mm x 6 kg/cm² was run at centre of the field. Laterals of telescopic fitting with 32 mm x 8 kg/cm² and 25 mm x 10 kg/cm² were run on both sides of the sub-main line.

A plot size of 120m x 84m with a water source at centre of the field was taken as another option for design purpose as shown in Fig 3.2.

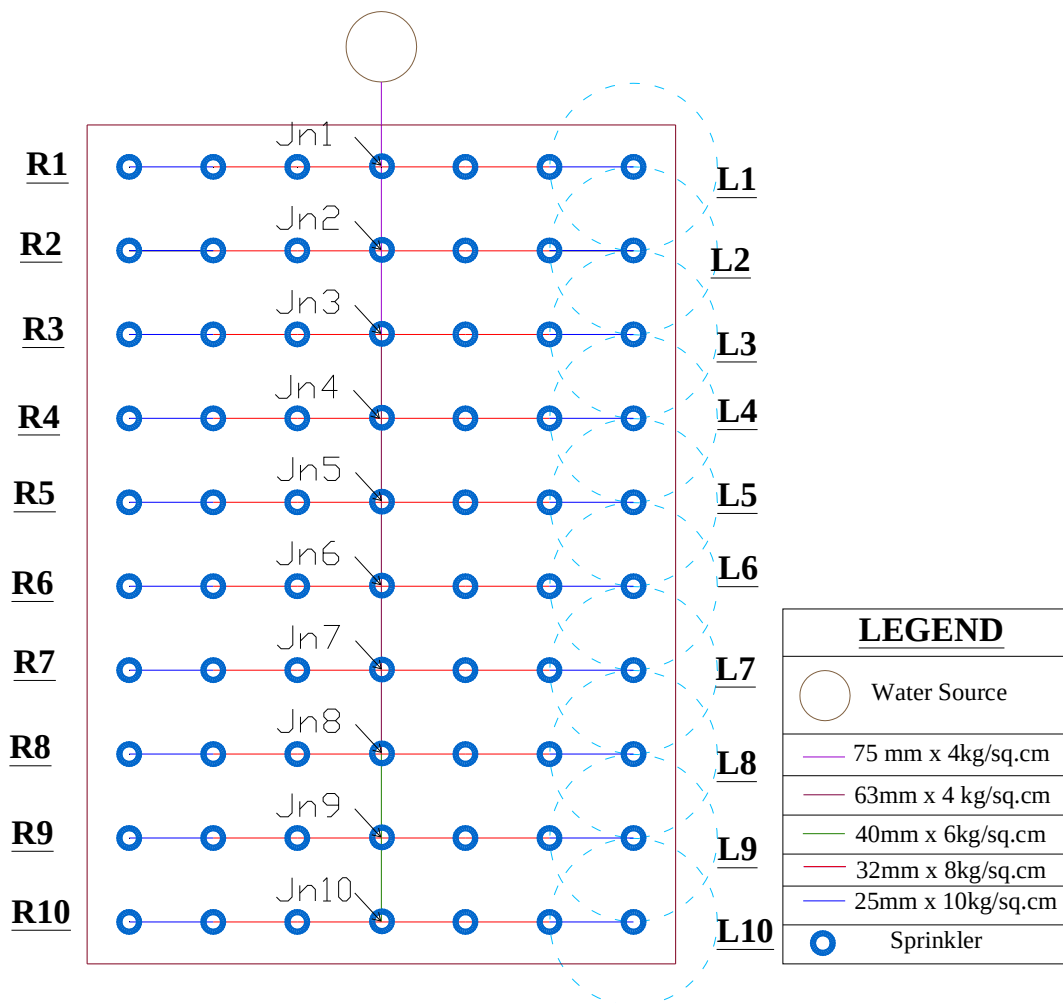
3.10 Hydraulic Performance of Designed SPSI System

A cost effective SPSI system as per the hydraulically efficient design was installed in farmers field at Sy.No.264, Thimmajigudem H/o Kangal revenue village and Mandal, Nalgonda District. A farm pond adjacent to the field was selected as a water source for installation of the designed SPSI system. An open well submersible pump set of 5 hp from CRI company make with a head range of 28 m to 36 m and discharge rate ranges from 10 lps to 5 lps was installed in the farm pond and connected to sprinkler system. With the use of PVC pipes 75 mm X 4 kg/cm², 63 mm X 4 kg/cm², 40 mm X 6 kg/cm², 32 mm X 8 kg/cm² and 25 mm X 10 kg/cm², SPSI system was installed as per the design shown in Fig 3.1

The hydraulic performance study, mainly depending on two most important parameters (i) pressure and (ii) discharge was conducted. Pressures of the system at different sprinkler nozzles were measured by using a pressure gauge fitted with pitot tube placing in orifices of sprinkler head nozzle. This method was chosen with an advantage of easy and reasonable

accuracy under point of consideration. Discharge of sprinkler heads was measured by fixing the flexible tubes to nozzle orifices and collecting the water from those tubes in to measuring bucket.

The readings of pressure, radius of throw and discharge practically measured and tabulated



Position no.1 of semi permanent sprinkler irrigation system while in operation

Fig. 3.1 Design Layout of SPSI System

3.11 Comparative Performance Evaluation of SPSI System with Conventional Portable Systems

Performance of these pressurized irrigation systems mainly depends on “Pressure” which automatically influences the “discharge” and “spray pattern” of sprinklers. As mentioned in the

above sections of this Chapter, with the use of pressure gauge fitted with pitot tube, the pressure of designed SPSI system, installed in farmer field of Nalgonda District, already existing portable sprinkler irrigation systems (Control) and some of SPSI Systems installed by Nandi Irrigation Systems in about 18 farmers fields of Ananthapur, Kadapa and Nalgonda Districts of Andhra Pradesh were measured and readings as against the Farmers (Plate 3.1), their area extent, crop under the system were collected and tabulated and given in Appendix – E (a sample data sheet used for collecting information from the farmer was also given).





Plate 3.1 Interaction with farmers during performance evaluation of sprinkler system at field level

The performance evaluation of SI's at field level is conducted by calculating Uniformity Coefficient using the Christiansen (1942) formula as given below:

$$C_u = 100 \left[1.0 - \frac{\sum X}{mn} \right] \quad (3.15)$$

where,

m = average value of all observations (average application rate) mm/hr

n = total no. of observation points

X = numerical deviation of individual observations from the average application rate, mm/hr

Overlapping area of four sprinklers placed in a square pattern was divided in to 16 small square plots. Catch can's were placed at centre of each square plot as shown in Figure 3.3. The precipitation rates obtained in the Catch cans were measured and its average was calculated. The numerical absolute deviations of each precipitation rate from the average was calculated. The C_u

values were calculated by using the equation 3.15 at the operating pressures of 2.5, 1.8 and 1.0 kg/cm². The data was tabulated.

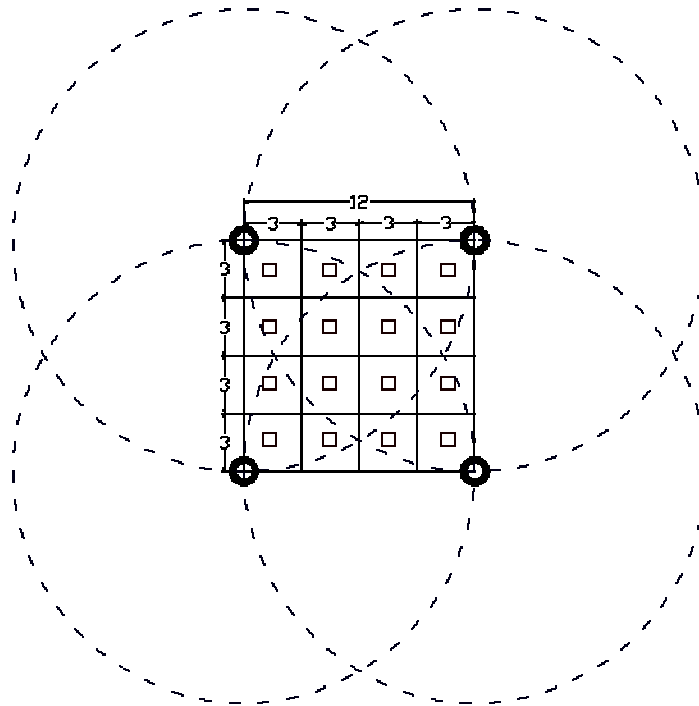


Fig. 3.2 Distribution coverage pattern under four sprinklers



Chapter-IV

Results and Discussion

Chapter- IV

RESULTS AND DISCUSSION

A study was conducted on “The performance of sprinkler irrigation systems (Portable and Semi-permanent) installed in the farmers fields of different districts of Andhra Pradesh”. The parameters like pump selection, power and labour availability were considered for the design of a cost effective hydraulically efficient semi-permanent sprinkler irrigation system.

The parameters which were mainly effect the performance of sprinkler irrigation systems were studied at farmers and experiment level. Performance of the Semi-permanent sprinkler irrigation systems and portable sprinkler irrigation systems at different operating pressures were compared and the results were presented through the tables.

4.1 Design of Cost effective hydraulically efficient Semi - Permanent Sprinkler Irrigation System (SPSIS)

As per the design considerations and procedures explained in the chapter III, the cost effective SPSI system was designed. An example calculation sheet of head losses in sub-mainlines and lateral lines are given in Appendix-I. The design layout of SPSI system for this study with telescopic sub-mainline and telescopic lateral lines were given in Fig 3.1 & 3.2. The head loss values for submain line and lateral lines are presented in Table 4.1.1 and 4.1.2.

The head loss was calculated for submain pipe sizes of 75mm, 63mm and 40mm for the total length of 36m, 60m and 24m respectively. The flow discharge through 75mm at 3 segments of 12m long was 5, 4.5, & 4 lps. The no. of outlets considered was 3 on one side. So, the total head loss calculated for 75mm pipe for the length of 36m was 0.65m. Similarly, the total head loss for 63mm pipe (60m long) and for 40mm pipe (24 m length) were 0.97m and 0.44 respectively (Table 4.1.1). The total head loss in submain with three telescopic pipe diameters was observed to be 2.06m which was within the permissible limits (< 20% of operating pressure) of design criterion.

The head loss in the lateral pipe of diameter 32mm, 25mm and riser of 25mm are presented in Table 4.1.2. The total head loss in 32mm pipe for a length of 24m was 0.63m. The same head loss was 25mm for a length of 12m was found to be 1.21m. The head loss for riser pipe of 25mm dia of 1.5m long was calculated as 0.15m. The total head loss in the lateral was 1.99m.

As seen from the two tables the system total head loss considering both submain and lateral was 4.05m which is within the permissible limits of pressure variation in the SPSI system.

The previous designs of semi-permanent sprinkler irrigation system which were available with a uniform size of sub mainline and uniform lateral. To reduce the cost of semi-permanent irrigation system for some extent, a telescopic design was taken for this study.

Table 4.1.1 Head loss due to friction in sub main of SPSI system

S.No	Pipe size	Total length, m	Flow through different pipe segments, lps	Number of outlets	Min head, m	Head loss
1	75 mm	36 m (12+12+12)	5, 4.5 & 4	3 on one side	24.35m	0.65 m (0.22+0.22+0.21)
2	63mm	60m (12+12+12+12+12)	3.5, 3.0, 2.5, 2.0 & 1.5	5 on one side	23.38m	0.97 m (0.33+0.22+0.21+0.11+ 0.1)
3	40 mm	24 m (12+12)	1.0 & 0.5	2 on one side	22.94	0.44 m (0.33+0.11)

A SPSI system was designed for 1 ha area with 120 x 84 m dimensions. The pressure head available in nodal points of submain, lateral pipes were given in Table 4.1.3. The total head loss in the SPSI system was observed to be 3.9 m (excluding head losses in the riser pipes) when the inlet pressure considered was 25 m head and sprinklers operated at 36 m away from one side of submain. When the head loss in riser pipes was taken in to consideration, the total system head loss was 4.05 m.

Table 4.1.2 Head loss due to friction in Lateral of SPSI system

S.No	Pipe size	Total length, m	Total flow, lps	Number of outlets	Head loss, m
1	32 mm	24 (12+12)	0.5	One at a time	0.63 m (0.30+0.33)
2	25 mm	12	0.5	One at a time	1.15 m
3-	Riser 25mm	1.5 m	0.5	---	0.15 m

Sprinklers at 24m away from one side of the submain with an entrance pressure of 2.5 kg/cm^2 (i.e., 25m head) at inlet of mainline (assumed 6m from pump), the total head loss observed was 2.69m(2.84 m inclusive of head loss in riser pipes). Similarly, when the system was operated with sprinklers at 12 m away from one side of the submain and exactly on submains and lateral node points, the head losses observed were 2.36 and 2.06 m (2.51 and 2.21 m inclusive of head loss in riser pipes) respectively.

From the Table 4.1.3, it was evident that there was further scope to increase lateral length. Therefore, the length of lateral was increased to 48 m to position one more sprinkler row. The total head loss calculated when 48 m long lateral pipe considered was 4.97 m excluding riser pipe losses. When head loss in riser pipes was included, the system total head loss was 5.12 m exceeding the design criterion of pressure variation of 20% in the system. Therefore, the SPSI system designed for 36 m telescopic lateral was considered for performance evaluation which is within the permissible pressure variation (Table 4.1.4).

Table 4.1.3 Calculated pressure heads at emission points with 12 m interval with Ds 75 mm, 63mm& 40mm and D_i 32 mm & 25mm pipes in 1 ha area (120 m x 84 m). (Maximum length of lateral was taken up to 36m)

Distance along the sub	Sub main size, mm	Distance along the lateral on both sides of sub main, m

main. m		36	24	12	0	12	24	36
6	75	22.94	24.15	24.48	24.78	24.48	24.15	22.94
18	75	21.25	22.35	24.26	24.56	24.26	23.93	22.72
30	75	22.51	23.72	24.05	24.35	24.05	23.72	22.51
42	63	22.18	23.39	23.72	24.02	23.72	23.39	22.18
54	63	21.96	23.17	23.50	23.80	23.50	23.17	21.96
66	63	21.75	22.96	23.29	23.59	23.29	22.96	21.75
78	63	21.64	22.85	23.18	23.48	23.18	22.85	21.64
90	63	21.54	22.75	23.08	23.38	23.08	22.75	21.54
102	40	21.18	22.39	22.72	23.05	22.72	22.39	21.18
114	40	21.10	22.31	22.64	22.94	22.64	22.31	21.10

Table 4.1.4 Calculated pressure heads at emission points with 12 m interval with D_s 75 mm, 63mm& 40mm and D_i 32 mm & 25mm pipes in 1 ha area (120 m x 84 m). (Maximum length of lateral was taken up to 48m)

Distance along the sub main. m	Sub main size, mm	Distance along the lateral on both sides of sub main, m								
		48	36	24	12	0	12	24	36	48
6	75	21.65	22.94	24.15	24.48	24.78	24.48	24.15	22.94	21.65

18	75	21.43	21.25	22.35	24.26	24.56	24.26	23.93	22.72	21.43
30	75	21.22	22.51	23.72	24.05	24.35	24.05	23.72	22.51	21.22
42	63	20.89	22.18	23.39	23.72	24.02	23.72	23.39	22.18	20.89
54	63	20.67	21.96	23.17	23.50	23.80	23.50	23.17	21.96	20.67
66	63	20.46	21.75	22.96	23.29	23.59	23.29	22.96	21.75	20.46
78	63	20.35	21.64	22.85	23.18	23.48	23.18	22.85	21.64	20.35
90	63	20.25	21.54	22.75	23.08	23.38	23.08	22.75	21.54	20.25
102	40	19.89	21.18	22.39	22.72	23.05	22.72	22.39	21.18	19.89
114	40	19.81	21.10	22.31	22.64	22.94	22.64	22.31	21.10	19.81

4.2 Hydraulic Performance of SPSI system

The designed SPSI system as per layout shown in Fig. 3.1 was installed at farmers field which was technically feasible and all the conditions were favorable to conduct an experiment for evaluation of performance at different operating pressures (Plate 4.1). The Operating pressure of SPSI system was measured by fixing a pressure gauge on main line as shown in Plate 4.2.a. The pressure at different sprinkler nozzle outlets of the system was measured by using a pressure gauge fitted with pitot tube as shown in Plate 4.2.b. The precipitation rates obtain in the catch cans were measured (Plate 4.3.b.) and its average was calculated (Appendix-C).The radius of throw of different sprinkler heads at different operating pressures were measured with the help of measuring tape. The discharge of sprinkler nozzles was measured by using two flexible pipes in to a bucket in an unit time (Plate 4.6.a.). All the data related to measured in the field system are recorded and analyzed for calculating precipitation rate, evaporation & drift losses and co-efficient of uniformity. The results of the above data analysis are presented in the Table 4.2.1.





Plate 4.1 Installation of sub main, lateral and riser



Plate 4.2.a. Measurement of pressure using pressure gauge on main line



Plate 4.2.b. Measurement of pressure at sprinkler nozzles



Plate 4.3.a. Measurement of sprinkler nozzle pressure with manometer



Plate 4.3.b. Experimental setup for measurement of Precipitation

Table 4.2.1 Uniformity co efficient of SPSI at different operating pressures

S. No.	Placement of Sprinklers (m x m)	Operating pressure (Kg/cm ²)	Radius of throw (m)	Discharge of nozzle (lps)	Precipitation rate (mm/hr)		Evaporation & Drift Losses (%)	Co-efficient of Uniformity (%)
					Calculated	Measured		
1	12 x 12	2.5	15	0.67	16.75	15.55	7.13	91.1
2	12 x 12	1.8	12	0.50	12.5	11.54	7.68	83.8
3	12 x 12	1.0	9	0.40	10.00	9.73	2.70	79.2

The pressurized system of irrigation is rated satisfactory when their uniformity co-efficient (C_u) is more than equal to 85%. The uniformity depends on operating pressure, manufacturing variation within nozzles and the existing weather conditions in the site (Plate 4.4.a). The C_u obtained for the SPSI system designed was formed maximum (91.1%) at an operating pressure of 2.5 kg/cm² suggesting that the variations in the precipitation are less 10%. However, in general, at farmers field the maintaining operating pressure of 2.5 kg/cm² is seldom available for achieving the above performance with uniformity greater than 90%. The system was then tested for two different low operating pressures of 1.8 and 1.0 kg/cm² (Plate 4.4.b). The C_u values decreased as the pressure reduced and the system performance was not acceptable as the C_u obtained was less than 85% (Appendix-C)

4.3 Comparison of Portable and SPSI system

The parameters involved in the cost analysis of both portable and SPSI systems were given in Table 4.3.1. The annual cost of the portable and SPSI systems for 1 ha irrigation had been worked out and the details were presented in Table 4.3.2. Life periods of 10 and 20 years for portable and SPSI systems were considered respectively in the annual cost estimation. The rate of interest was taken as 12% per annum. The total annual cost of both the systems were calculated and found that there was reduction of 60.64% in the annualized cost.



a



b

Plate 4.4 Sprinklers operation a) Optimum pressure b) Low pressure

Table 4.3.1: Analysis of parameters considered in the portable and SPSI system

Parameter	Portable system	Semi-permanent system
Length of pipes required	a) 50/63/75 mm size HDPE pipe of 150 m for 1 ha (25 HDPE pipes of 6 m length each) b) 25 mm GI pipes of 5 m length for riser	75/63/40 mm size PVC pipe of telescopic 120 m (36+60+24) for submain a) 32mm & 25 mm size PVC pipe of 825 m (480+345) for, telescopic lateral and risers
Number of sprinkler heads provided	5 heads with 1 ha unit irrespective of pump discharge	10 number of sprinkler heads can be operated with a pump discharge of 5 lps
Shifting time of pipes	Every shift takes 20-30 minutes where pump set operation was to be kept in ON & OFF mode (Plate 4.5.a & 4.5.b)	No shifting of pipes required hence no loss of operation time. But 10 min of time required for shifting of only sprinkler heads.
Cost of the system	Rs 15,000 per unit	Rs 37,500 per ha in addition to the trenching cost of Rs 10,000.
Water leakages	At Quick Action Couplers water seeps from the ends of pipes when dismantled and causes marshy condition (Plate 4.6.b).	No seepage and ponding of water since opening of pipes not require
Safety of equipment	The portable systems generally carried from farmers house to avoid theft problem. Since the heads are made of brass they are prone for theft	Since the pipes were buried and sprinkler heads made of plastic no theft problem. Only sprinkler heads can be carried easily for storarge.
Labor required	For movement of the pipes two laborers	One person can operate with ease

	are required	
Laying of pipes	On surface of the ground	Pipes are buried underground at 60 cm depth
Portability	Entire system is portable. Hence the same unit used in other fields also	Only sprinkler heads are portable. The advantage of portability is lost.
Farmers preference	It is less preferred	Due to shortage of labor and limited power supply created more demand
Repairs & maintenance	The cost towards repairs and maintenance is double than SPSI due to frequent replace of gaskets watchers and springs etc.	Only springs of sprinklers are to be replaced. Cost is very low compare to the portable
Transportation cost	Transportation of equipment is necessary to avoid the thefts in the field. It is very costly affair.	No transportation was required.



a



b

**Plate 4.5 a) Carrying of pipes and accessories in
portable system**

b) Installation of portable system



Plate 4.6.a Measurement of sprinkler nozzle discharge



Plate 4.6.b Leakages observed from Quick Action Coupler (QAC) in portable sprinkler irrigation system

Table 4.3.2 Comparison of Annual Costs of the Portable and SPSI Systems for 1 ha Operation

Parameter	Portable Sprinkler Irrigation System	Semi-Permanent Sprinkler Irrigation system
1. Cost of Unit		
a. Cost of equipment	Rs. 15000.00	Rs. 27500.00
b. Trench digging & back filling plus installation	Nil	Rs. 10,000/-
Total	Rs. 15,000.00	Rs. 37,500.00
2. Life of the system	10 years	20 years
3. Capital Recovery Factor (i=12% p.a.) (Ref Appendix-D)	0.176	0.134
4. Annual Fixed Cost (AFC) (Ref Appendix-D)	Rs. 2,640.00	Rs. 5,025.00
5. Annual Operating Cost(AOC) (Ref Appendix-D)		
a. Energy Cost	Rs. 1848.00	Rs. 1680.00
b. Repairs and Maintenance	Rs. 1125.00	Rs. 550.00
c. Transportation of equipment from	Rs. 8000.00	Nil

storage place to the field		
d. Manpower Cost	Rs. 6600.00	Rs. 700.00
Total	Rs. 17,573.00	Rs. 2,930.00
6. Total Annual Cost (AFC + AOC)	Rs. 20,213.00	Rs. 7,955.00

The cost benefit analysis for both the system was done based on the yield and cost of cultivation data for ground net crop collected from the framers using the sprinklers (Plate 4.7). The data presented in table 4.3.3 indicated that the SPSI for 1 ha area was observed more beneficial as cost benefit ratio was 1:1.98 as compared to portable sprinkler irrigation system of 1:1.07. Therefore, the SPSI system was found more beneficial along with its efficient hydraulic performance as the variations in the discharge and pressure were within permissible limits of 10% & 20% respectively





Plate 4.7 Ground nut and Sunflower irrigated with SPSI system in the farmers field

Table 4.3.3 Cost Benefit ratio of Portable SI and SPSI Systems

Parameters	Cost of Cultivation (1 ha Ground nut)	
	Portable Sprinkler Irrigation system	Semi-permanent Sprinkler Irrigation system

1.Land preparation	Rs. 3750.00	Rs. 3750.00
2. Seed	Rs. 7500.00	Rs. 7500.00
3. Inter cultivation	Rs. 2500.00	Rs. 2500.00
4. FYM	Rs. 1250.00	Rs. 1250.00
5.Chemical fertilizers	Rs. 2500.00	Rs. 2500.00
6. Crop Management	Rs. 7500.00	Rs. 7500.00
7. Harvesting	Rs. 6250.00	Rs. 6250.00
8. Total Annual Cost of irrigation system	Rs. 20213.00	Rs. 7955.00
Total Cost	Rs. 51,463.00	Rs. 39,205.00
9. Yield	27.5 qntls.	30 qntls
10. Cost of Produce sold at Rs.3500	Rs. 96250.00	Rs. 105000.00
11. Realization from fodder	Rs. 10000.00	Rs. 12000.00
Gross Profit	Rs. 1,06,250.00	Rs. 1,17,000.00
Net Profit	Rs. 54,787.00	Rs. 77,795.00
Cost benefit ratio	1 : 1.07	1 : 1.98



Chapter-V

Summary and Conclusions

Chapter - V

SUMMARY AND CONCLUSIONS

5.1 Summary

Water is a critical resource in achieving the desired productivity levels in different production systems. The management of such resource which is very scarce and distributed over space and time is very important with reference to agriculture. It can be managed by selecting proper irrigation system in the field. The proper design of any irrigation system is vital to cost reduction and its efficient operation. The portable sprinkler systems are very common and adopted by the farmers. In the present study, a semi-permanent sprinkler irrigation system designed to overcome the deficiencies in the portable sprinkler system.

While studying the performance of the existing portable systems and some SPSI systems adopted by the farmers in Ananthapur, Kadapa and Nalgonda Districts, it was observed that almost all the systems were operating at a low pressure (i.e., pressure ranges from 0.9 to 1.2 kg/cm²), due to which the spray pattern of sprinklers was non uniform. In case of portable conventional sprinkler irrigation system, with the observation of less coverage & overlapping, the farmers practice was found as placing the sprinklers immediately on lateral at an interval of 6m distance instead of 12m.

The present study mainly focused on the design of semi-permanent sprinkler irrigation system with some improvements on recent past with such designs which are already available and in practice by the farmers in some parts of Andhra Pradesh. The performance of the latest developed i.e., designed semi-permanent sprinkler irrigation system was evaluated at field level

and the results were compared with the performance of previously existing such systems in addition to several conventional portable sprinkler irrigation systems.

The performance of sprinkler irrigation system developed at present and the conventional system as control was evaluated based on Christiansen Uniformity coefficients (CUCs) by using Catch Can method. It was observed that the CUC of developed semi-permanent sprinkler irrigation system was 91.1% when system operating pressure was 2.5 kg/cm^2 with two nozzle rotating impact sprinkler at a discharge of 0.67 lps. This practical study was conducted at farmers' fields where a pump meeting the requirements of system head and discharge was installed for operating the developed semi-permanent sprinkler irrigation system.

Besides the design of efficient SPSI system along with its hydraulic performance, the cost analysis was also done to both portable and SPSI systems for comparison. It was observed that the total annual cost reduction in the SPSI system was 60.64% over the portable sprinkler irrigation system. The benefit cost analysis was also done for groundnut crop by collecting data from the farmers in relation to crop yield and cost of cultivation. The analysis indicated that the SPSI system was more beneficial to the farmers over the portable sprinkler irrigation system as the BC ratio was more for SPSI (1:1.98) than the portable sprinkler irrigation system (1:1.07). Therefore, the designed hydraulically efficient SPSI system can be adopted by the farmers.

5.2 Conclusions

From the present study, the following conclusions were drawn:

1. The total system head loss with the telescopic submain (75mm Ø for 36m, 63mm Ø for 60m and 40 mm Ø for 24m), telescopic laterals (32 mm for 24m and 25 mm for 12 m) and risers of 25mm Ø for 1.5 m long was observed to be 3.99m. Whereas the telescopic lateral was extended to 48m (32 mm Ø for 24m and 25 mm Ø for 24m, keeping the riser dimensions as same), the total system head loss was found to be 4.97m. The total system head losses in above cases were found to be within the permissible limits of 20% allowable pressure variation within the system from the operating pressure of 25m head.

2. The hydraulically efficient and cost effective SPSI system was designed, installed and tested. Based on the performance test data the co-efficient of uniformity (C_u) was found to be 91.1% at operating pressure of 25m head (2.5 kg/cm^2). The system was also evaluated for low pressures (1.8 and 1.0 kg/cm^2), the uniformity co-efficients obtained were less than 85% falling in the unsatisfactory performance level. Therefore, operation of sprinkler system at recommended operating pressure is much more important and accordingly selection of suitable pump was found to be essential to meet the designed head and discharge. So, that the desired system performance could be achieved at the field level.
3. The total annual cost for both portable SI and SPSI systems were estimated and found that there was a cost reduction of 60.64% in SPSI system (Rs. 7,955.00) over the portable SI system (Rs. 20,213.00). Taking these total annual costs of both the systems into the account and field data collected like crop yield and cost of cultivation from the farmers the benefit cost ratio was calculated. It was observed that the SPSI system designed was more beneficial with B:C ratio of 1:1.98 over the portable SI system (B:C ratio of 1:1.07). Therefore, the SPSI system designed in the present study was found cost effective over the portable sprinkler irrigation system for the farmers.

From the field evaluation of existing portable and SPSI systems in the districts of Ananthapur, Kadapa and Nalgonda all the systems were operating at low pressure range of 0.9 to 1.2 kg/cm^2 due to which the spray pattern of sprinklers was found non uniform and the systems were found to be hydraulically inefficient in the farmers field. This may be due to the fact that there was no suitable pump sets were matching the system discharge and pressure requirements.

SUGGESTIONS FOR FUTURE WORK

In Andhra Pradesh more than 30 lakh pump sets are under operation by the farmers for irrigation. In order, to improve the overall system productivity in agriculture sector, it is required to select an efficient and appropriate technology which reduces the resource consumption like ground water, pumping energy and farm labor.

The semi-permanent sprinkler irrigation system (SPSI) designed in the present study must be scaled up in minor irrigation commands, where the pumps are extensively used. This system will save the farm labor, energy and ground water usage. However, the SPSI system requires trench work which was a financial constraint to the farmers and this can be overcome by converging the trench work with Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) program implemented by Government of India in Andhra Pradesh. Based on the advantages realized with the system studied by the author, the following suggestions are enlisted for future study.

1. Research on development of sprinkler heads and mini rain guns to operate at low pressures up to 2.5 kg/cm^2 with better radius of throw & coverage was essential. With this cost of SPSI System should be brought down reasonably by reducing the length of laterals.
2. The hardened plastic made rain guns and sprinkler heads have come into market and need to be tested to confirm their performance efficiency which will further reduce the cost.

Decision Support System(DSS) & Expert System softwares can be prepared and standardized for micro irrigation (MI) companies to decide the design parameters in the farmer fields of any extent for various possible situations.



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Appendices

APPENDIX-A

CALCULATION OF HEAD LOSSES

Head losses due to friction for different flows through different segments of pipe network were calculated for designed semi-permanent sprinkler irrigation system by using both hydrocalc software based on Darcy's – Weisbach and Hazen Williams formula.

Head Losses through Submain & Main:

1. H_{f1} (head loss for a length of submain between junction no 10 & 9)

$$= 1.213 \times 10^{10} \times \left(\frac{0.5}{140}\right)^{1.852} \times \frac{1}{(36.4)^{4.87}} = 0.009 \times 12 = 0.11 \text{ m}$$

By using Hydrocalc software = **0.11m**

2. H_{f2} (head loss for a length of submain between junction no 9 & 8)

$$= 1.213 \times 10^{10} \times \left(\frac{1}{140}\right)^{1.852} \times \frac{1}{(36.4)^{4.87}} = 0.032 \times 12 = 0.39 \text{ m}$$

By using Hydrocalc software = **0.33m**

3. H_{f3} (head loss for a length of submain between junction no 8 & 7)

$$= 1.213 \times 10^{10} \times \left(\frac{1.5}{140}\right)^{1.852} \times \frac{1}{(59.2)^{4.87}} = 0.0064 \times 12 = 0.076 \text{ m}$$

By using Hydrocalc software = **0.10m**

4. H_{f4} (head loss for a length of submain between junction no 7 & 6) = 1.213×10^{10}

$$X \left(\frac{2}{140} \right)^{1.852} X \frac{1}{(59.2)^{4.87}} = 0.011 \times 12 = 0.13 \text{ m}$$

By using Hydrocalc software = **0.11m**

5. H_{f5} (head loss for a length of submain between junction no 6 & 5)

$$= 1.213 \times 10^{10} X \left(\frac{2.5}{140} \right)^{1.852} X \frac{1}{(59.2)^{4.87}} = 0.016 \times 12 = 0.196 \text{ m}$$

By using Hydrocalc software = **0.21m**

6. H_{f6} (head loss for a length of submain between junction no 5 & 4)

$$= 1.213 \times 10^{10} X \left(\frac{3}{140} \right)^{1.852} X \frac{1}{(59.2)^{4.87}} = 0.02299 \times 12 = 0.28 \text{ m}$$

By using Hydrocalc software = **0.22m**

7. H_{f7} (head loss for a length of submain between junction no 4 & 3)

$$= 1.213 \times 10^{10} X \left(\frac{3.5}{140} \right)^{1.852} X \frac{1}{(59.2)^{4.87}} = 0.031 \times 12 = 0.37 \text{ m}$$

By using Hydrocalc software = **0.33m**

8. H_{f8} (head loss for a length of submain between junction no 3 & 2)

$$= 1.213 \times 10^{10} X \left(\frac{4}{140} \right)^{1.852} X \frac{1}{(70.6)^{4.87}} = 0.017 \times 12 = 0.199 \text{ m}$$

By using Hydrocalc software = **0.21m**

9. H_{f9} (head loss for a length of submain between junction no 2 & 1)

$$= 1.213 \times 10^{10} X \left(\frac{4.5}{140} \right)^{1.852} X \frac{1}{(70.6)^{4.87}} = 0.021 \times 12 = 0.25 \text{ m}$$

By using Hydrocalc software = **0.22m**

10. H_{f10} (head loss for a length of submain between junction no 1 & 0)

$$= 1.213 \times 10^{10} X \left(\frac{5}{140} \right)^{1.852} X \frac{1}{(70.6)^{4.87}} = 0.025 \times 12 = 0.30 \text{ m}$$

By using Hydrocalc software = **0.22m**

TOTAL HEAD LOSS DUE TO FRICTION THROUGH THE SUBMAIN =

$$H_{f1} + H_{f2} + H_{f3} + H_{f4} + H_{f5} + H_{f6} + H_{f7} + H_{f8} + H_{f9} + H_{f10} = 0.11 + 0.39 + 0.10 + 0.13 + 0.20 + 0.28 + 0.37 + 0.20 + 0.25 + 0.30 = \mathbf{2.30\ m}$$

By using Hydrocalc software = **1.95m**

Head Losses through Laterals and Risers

1. $H_{f32\text{mm}}$ (head loss for lateral of 32mm pvc pipe length- 24m)

$$= 1.213 \times 10^{10} \times \left(\frac{0.5}{140}\right)^{1.852} \times \frac{1}{(28.2)^{4.87}} = 0.031 \times 24 = 0.74\ \text{m}$$

By using Hydrocalc software = **0.63m**

2. $H_{f25\text{mm}}$ (head loss for lateral of 25mm pvc pipe length- 12m)

$$= 1.213 \times 10^{10} \times \left(\frac{0.5}{140}\right)^{1.852} \times \frac{1}{(21.4)^{4.87}} = 0.113 \times 12 = 1.42\ \text{m}$$

By using Hydrocalc software = **1.21m**

3. $H_{f25\text{mm-riser}}$ (head loss for a riser pipe of 25mm pvc pipe length- 1.5m)

$$= 1.213 \times 10^{10} \times \left(\frac{0.5}{140}\right)^{1.852} \times \frac{1}{(21.4)^{4.87}} = 0.113 \times 1.5 = 0.169\ \text{m} \approx 0.17\ \text{m}$$

By using Hydrocalc software = **0.15m**

TOTAL HEAD LOSS DUE TO FRICTION THROUGH THE LATERAL LINE AND RISER PIPE= $H_{f32mm} + H_{f25mm} + H_{f25mm-riser} = 0.74 + 1.42 + 0.17 = 2.33m$

By using Hydrocalc software = **1.99m**

Table 3.1 Size and length of PVC pipe sections for various flows and head losses in laterals and risers.

Size and length of PVC pipe sections	Flow through the pipe (lps)	Head loss due to friction calculated (m)
25 mm, 12 m lateral	0.5	1.42
32 mm, 24 m lateral	0.5	0.74
25 mm, 1.5 m riser	0.5	0.17
Total head loss in lateral and riser		2.33

Table 3.2 Size and length of PVC pipe sections for various flows and head losses in sub-main

Size and length of PVC pipe	Flow through the pipe (lps)	Head loss due to friction calculated (m)
40 mm, 12 m submain	0.5	0.11
40 mm, 12 m submain	1.0	0.39
63 mm, 12 m submain	1.5	0.10
63 mm, 12 m submain	2.0	0.13
63 mm, 12 m submain	2.5	0.2
63 mm, 12 m submain	3.0	0.28
63 mm, 12 m submain	3.5	0.37

75 mm, 12 m submain	4.0	0.20
75 mm, 12 m submain	4.5	0.25
75 mm, 12 m submain	5.0	0.30
Total head loss in submain		2.33

Hydraulic Calculations

Design for 1 hectare:

Pump discharge : 5 lps

Pressure requirement : 2.5 kg/cm²

Pipe sizes : 75/ 63 mm for submains

: 32/ 25 mm for lateral

Sprinkler discharge : 0.5 lps

Effective Rainfall / Precipitation rate: 12.5 mm/hr

Average depth of application : 2.0 cm

Number of sprinkler heads that can be operated: 10.

Area that can be covered by one setting: 1440 sq m

Power availability : 7 hrs

Operating time : 6.4 hrs

Number of shifts per day : 4

Time for each shift : 1.6 hrs (96 min)

Area that can be irrigated per day: 5,760 sq m

APPENDIX – B

Selection of suitable pump set

The total head required for a pump set was calculated on the basis of values presented in Table no. 4.1.1 & 4.1.2.

Total Head (head losses based on Hazen Williams formula) =

Head loss in lateral and riser (2.33 m) + Head loss in submain (2.33 m) + Head loss in main (0.6 m) (if the water source is 36 m away from the field) + Operating head (25 m) + Pumping head (2m) (farm pond depth) + Head loss through fittings (2.0 m) + Height of riser (1.5m) = **35.76 m**

Total Head (head losses calculated by using hydrocalc software) =

Head loss in lateral and riser (1.95 m) + Head loss in submain (1.99m) + Head loss in main (0.6 m) (if the water source is 36 m away from the field) + Operating head (25 m) + Pumping head (2m) (farm pond depth) + Head loss through fittings (2.0 m) + Height of riser (1.5m) = **35.04 m**

As per the required head and discharge, an open well submersible pump set of 5hp capable of giving 5lps at 36m head was selected from CRI company make.

APPENDIX-C

Calculations of the uniformity coefficient under SPSI system at different pressures

Rainfall fall in to these can's for one hour operation of designed semi- permanent sprinkler irrigation system operated at 2.5 kg/cm^2 was measured with a measuring jar and readings were noted as given in Table 4. 1

Table No. 4.1 Quantity of water measured at different 16 plots under SI system (all in mm/hr)

5.77	14.42	8.65	9.23
7.21	8.1	9.23	8.65
7.21	7.21	8.65	6.35
7.21	11.54	8.65	5.77

Calculation of Co-efficient of Uniformity of an individual sprinkler head of semi-permanent sprinkler Irrigation system operated at 2.5 kg/cm^2 (as shown in table 4.2)

Table 4.2 Calculation of the Uniformity coefficient under SI system

Sl.No.	Observation rainfall (mm/hr) m	Frequency n	(Application rate) x (Frequency) mn	Numerical Deviation x _i	(Frequency) x (Deviations) X
1	5.77	2	11.54	2.6	5.2
2	6.35	1	6.35	2.02	2.02
3	7.21	4	28.84	1.16	4.64
4	8.1	1	8.10	0.27	0.27
5	8.65	4	34.6	0.28	0.28
6	9.23	2	18.46	0.86	1.72
7	14.54	1	14.54	3.17	3.17
8	14.42	1	14.42	6.05	6.05

$$\sum n = 16$$

$$\sum mn = 133.85$$

$$\sum X = 23.35$$

$$\text{Average of rainfall (observations)} = \sum mn / \sum n$$

$$= 133.85 / 16 = 8.37$$

$$C_u = 100 \left[1.0 - \frac{\sum X}{mn} \right]$$

$$= 100 \left[1.0 - \frac{23.35}{133.85} \right]$$

$$= 82.55 \%$$

Rainfall fall collected in to these cans for one hour operation @ 2.5 kg/cm², 1.8 kg/cm² and 1 kg/cm² under sprinkler irrigation system and measured with a measuring jar and readings were noted as in Tables 4.3, 4.4 and 4.5 respectively

Table No. 4.3

(mm/hr)

14.42	12.98	14.42	17.3
13.85	14.42	17.3	17.3
14.42	15.86	17.3	17.3
14.42	14.42	15.86	17.3

Table No. 4.4

(mm/hr)

7.21	8.65	9.3	14.42
6.1	7.21	10.1	12.98
11.54	12.98	14.42	15.86
12.10	12.98	17.3	11.54

Table No. 4.5

(mm/hr)

7.21	11.54	7.21	8.65
8.65	8.65	11.54	8.65
8.65	11.54	11.54	11.54
8.65	11.54	8.65	11.54

Calculation of Co-efficient of Uniformity under sprinkler Irrigation system operated at 2.5 kg/cm², 1.8 kg/cm² and 1 kg/cm² with placement of sprinklers at 12 m x 12 m. (as shown in tables 4.6, 4.7 and 4.8 resp.)

Table 4.6 Calculation of the Uniformity coefficient under SI system@ 2.5 kg/cm²

Sl.No.	Observation rainfall	Frequency	(Application rate) x	Numerical	(Frequency) x
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	(mm/hr) m	n	(Frequency) mn	Deviation x_i	(Deviations) X
1	12.98	1	12.98	2.57	2.57
2	13.85	1	13.85	1.70	1.70
3	14.42	6	86.52	1.13	6.78
4	15.86	2	31.72	0.31	0.62
5	17.3	6	103.8	1.75	10.5
$\sum n = 16$ $\sum mn = 248.87$ $\sum X = 22.17$					

Average of rainfall (observations) = $\sum mn / \sum n$

$$= 248.87 / 16 = 15.55$$

$$C_u = 100 \left[1.0 - \frac{\sum X}{mn} \right]$$

$$= 100 \left[1.0 - \frac{22.17}{248.87} \right]$$

= 91.1 % Table 4.6 Calculation of the Uniformity coefficient under SI system@

1.8 kg/cm²

Sl.No.	Observation rainfall (mm/hr) m	Frequency n	(Application rate) x (Frequency) mn	Numerical Deviation x_i	(Frequency) x (Deviations) X
1	6.1	1	6.1	5.44	5.44
2	7.21	2	14.42	2.88	5.76
3	8.65	1	8.65	2.89	2.89
4	9.3	1	9.3	2.24	2.24

5	10.1	1	10.1	1.44	1.44
6	11.54	2	23.08	0	0
7	12.1	1	12.1	0.56	0.56
8	12.98	3	38.94	1.44	4.32
9	14.42	2	28.84	2.88	5.76
10	15.86	1	15.86	4.32	4.32
11	17.3	1	17.3	5.76	5.76
$\sum n = 16$		$\sum mn = 184.69$		$\sum X = 38.49$	

$$\begin{aligned}\text{Average of rainfall (observations)} &= \sum mn / \sum n \\ &= 184.69 / 16 = 11.54\end{aligned}$$

$$\begin{aligned}C_u &= 100 \left[1.0 - \frac{\sum X}{mn} \right] \\ &= 100 \left[1.0 - \frac{38.49}{184.69} \right] \\ &= 79.2 \%\end{aligned}$$

Table 4.6 Calculation of the Uniformity coefficient under SI system@ 1.0 kg/cm²

Sl.No.	Observation rainfall (mm/hr) m	Frequency n	(Application rate) x (Frequency) mn	Numerical Deviation x _i	(Frequency) x (Deviations) X
1	7.21	2	14.42	2.52	5.04
2	8.65	7	60.55	1.08	7.56
3	11.54	7	80.78	1.81	12.67
$\sum n = 16$		$\sum mn = 155.75$		$\sum X = 25.27$	

$$\begin{aligned}\text{Average of rainfall (observations)} &= \sum mn / \sum n \\ &= 155.75 / 16 = 9.73\end{aligned}$$

$$C_u = 100 \left[1.0 - \frac{\sum X}{mn} \right] = 100 \left[1.0 - \frac{25.27}{155.75} \right] = 83.8 \%$$

APPENDIX -D

Calculations of various parameters of cost analysis

Capital Recovery Factor (CRF)

CRF worked out at the interest rate of 12% per annum

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1}$$

where, i = yearly interest rate, %, in fractions.

n = life period in years

CRF for the portable sprinkler irrigation system with life period of 10 years is

$$CRF = \frac{0.12(1+0.12)^{10}}{(1+0.12)^{10} - 1} = 0.176$$

CRF for the semi permanent sprinkler irrigation system with life period of 20 years is

$$CRF = \frac{0.12(1+0.12)^{20}}{(1+0.12)^{20} - 1} = 0.134$$

Annual Fixed Cost (AFC)

$$AFC = CRF \times I.I$$

where, I.I = Initial investment

$$AFC \text{ of portable sprinkler irrigation system} = 0.176 \times 15000 = \text{Rs. } 2640.00$$

$$AFC \text{ of semi-permanent sprinkler irrigation system} = 0.134 \times 37500 = \text{Rs. } 5025.00$$

Energy Cost

Energy cost worked out for 5 irrigations per season. Every irrigation requires 14 shifts of sprinkler systems operation to cover 1 ha of area. Each shift required 1.6 hrs of time for operation. For total season to cover 1 ha area required 112 hrs of operation, for one year operation 224 hrs. Energy consumption of 5 hp pump set per hour is 3.75 kwh.

$$\text{Cost of Energy per annum for SPSI system} = 224 \times 3.75 \times 2 = \textbf{1680.00}$$

(Charges @ Rs. 2/- per unit)

In portable sprinkler irrigation system, there may be a chance of water leakages about 10% minimum from Quick Action Couplers (QAC) of HDPE pipes. To compensate that wastages of

10%, sprinkler system has to be run for 10 % more time than the semi-permanent sprinkler irrigation system (246.4 hrs).

Cost of Energy per annum for portable system = $246.4 \times 3.75 \times 2 = 1848.00$

(Charges @ Rs. 2/- per unit)

Repairs and Maintenance

In portable system, frequent replacement of rubber gaskets of QA couplers, watchers at foot batten assembly and springs of impact sprinkler heads is required. A minimum of 7.5 % on system cost per annum is required to meet the expenses towards repairs and maintenance was a feedback from farmers.

Cost of repairs and maintenance for

portable system per annum = 7.5 % of Rs. 15,000

= Rs. 1125.00

In SPSI system, repairs to pipes & risers damage are very limited was a feedback from the present study and replacement cost of springs to the impact sprinkler heads is also very less. Hence, a minimum of 2% on SPSI system equipment cost was considered.

Cost of repairs and maintenance for SPSI system per annum = 2% of Rs. 27,500.00

= Rs.550.00

Transportation Cost

In portable system, pipes and all sprinkler accessories are to be carried from a storage place to the field and from field to the storage place after completion of system operation during the irrigation scheduling period. As mentioned earlier 14 shifts of system operation are required to irrigate 1 ha. Because of stipulated supply of electricity in 7 hrs, 4 shifts are only possible per

day, with this for every irrigation requires 3 ½ days (4 days). For total season irrigating 1 ha with 5 schedules, transportation of equipment has to be done on 20 days (40 days per annum). A minimum cost of transportation of equipment per day (to and fro) was taken as Rs. 200.00.

Cost of transportation of equipment per annum = 40 days x Rs. 200 = **Rs. 8000.00**

Man Power Cost

In portable system, two labourers are required to carry the equipment, install and shift the system. For irrigating 1 ha per season 70 shifts are required. Each shift requires on and off mode of pump set for a certain period is necessary. This on and off of pump set consumes at least 10 min (5+5) time of labourers. Carrying, assembling and dismantling of equipment per every shift consume at least 20 min time. The total 30 min time is required for every shift. (Man power cost per hr was taken as Rs. 30.00)

For loading and unloading of equipment to the transportation vehicle on the days of irrigation consumes at least 1 hr (30min + 30min) time for two labourers.

Man power hrs per season = (70 shifts of operation x 30 min per shift + 20 days of loading and unloading to the vehicle x 1hr per 1 day) x 2 members = **110 hrs**

(220 hrs per annum)

Man power cost per annum = 220 hrs x Rs. 30 per hr = **Rs. 6600.00**

In SPSI system, only 1 person is enough to shift the sprinkler heads. Here no need of keeping the pump set in on and off mode. Every shift requires a 10 min time for change of sprinklers from 1 row of risers to the adjacent row while system in operation.

Man power hrs per season = 70 shifts of operation x 10 min per shift = **11.67 hrs**

i.e 11hrs 40 min (23.34 hrs i.e 23 hrs 20 min per annum)

Man power cost per annum = 23.34 hrs x Rs. 30 per hr = **Rs. 700.00**

APPENDIX -E

S. N O	Farmers details	Land details			Water source details			Pump set details			
		Total extent (Acre s)	Area brought under sprinkler (Acres)	Type of soil	Type	Depth (m)	Distance to the field	Type	Hp	Head (m)	Discharge (lps)
1	Madavakunta vijaya BhaskarReddy, s/o Timmareddy Inagaluru(v), Thonduru(mandal), Kadapa(Dist.)	2.50	2.50	medium	Canal to sump	3	300	Open well submersible	5	28	9.0
2	Goddeti Narayana Reddy s/o pedda Thirupal Reddy Inagaluru(v),	6.00	6.00	medium	Canal to sump	3	300	Open well submersible	7.5	32	10.0

	Thonduru(mandal), Kadapa(Dist.)										
3	Aguduru Krishnamurthy s/o Jagannatha Rao Inagaluru(v), Thonduru(mandal), Kadapa(Dist.)	2.5	2.5	medium	Canal to sump	3	250	Open well subme rsible	5	28	9.0
4	Chappidi Ramana Reddy s/o C.V.Narayana Reddy Ankalamma Guduru(v),Simhadripura m(mandal), Kadapa(Dist.)	8.0	8.0	<u>medium</u>	Bore well	50	20	subme rsible	7.5/8 stage	73	5.0
5	Mode Munyanaik s/o Dhanseemanna Nagulaguddam Thanda(V), Singanamala(mandal),	5.0	5.0	Light	Bore well	43	1500	subme rsible	7.5/8 stage	73	4.0

	Ananthapuru(Dist.)										
6	Mode Badyanaik s/o Bhavyanaik Nagulaguddam Thanda(V), Singanamala(mandal), Ananthapuru(Dist.)	10.0	6.0	light	Bore well	40	300	subme rsible	6.0/6 stage	55	4.0
7	Ammaladinne Nallappa s/o Pedda Narappa Nagulaguddam (V), Singanamala(mandal), Ananthapuru(Dist.)	2.2	1.5	light	Bore well	76	With in the field	subme rsible	6.0/ 10sta ge	90	3.0
8	Poliki Venkatanarayanappa s/o Kullayappa Nagulaguddam (V), Singanamala(mandal), Ananthapuru(Dist.)	5.0	2.0	light	Bore well	61	With in the field	subme rsible	6.0/6 stage	55	4.0

9	Sri Challa Naidu, s/o Vobhulesh, Linga reddy palli (v), Sanjeeva puram(po), Batthula palli(m), Ananthapuram(Dist).	12.0	8.0	light	Bore well	50	With in the field	subme rsible	6.0/6 stage	55	4.0
10	Sri Challa Naranayana swamy,s/o Vobhulesh, Linga reddy palli (v), Sanjeeva puram(po), Batthula palli(m), Ananthapuram(Dist).	12.0	7.0	light	Bore well	55	At one side of the field	subme rsible	7.5/8 stage	55	5.0
11	Jakkamputi Praveen, s/o Nagabhushanam, Batthula palli (v)&(m), Ananthapuram (Dist).	6.0	4.0	light	Bore well	90	With in the field	subme rsible	12	90	3.0
12	Sri Raagechinna	5.0	5.0	light	Bore	80	With in	subme	7.5/8	73	3.0

	Kullayappa,s/o Ranganna, Gummallakunta(v), Batthula palli(m), Ananthapuram (Dist).				well		the field	rsible	stage		
13	Sri Varimadugu Nagi reddy, S/o Malli reddy, Gummallakunta (v), Batthula palli (mandal), Ananthapuram (Dist).	4.0	4.0	light	Bore well	83	With in the field	subme rsible	7.5/8 stage	73	3.0
14	Annagiri Narayana, s/o Pollanna, Mannila(v), Ananthapuram rural(mandal), Ananthapuram (Dist).	8.0	3.0	Light	Bore well	60	With in the field	subme rsible	7.5/5 stage	45	6.0
15	Sri Kovvuri Sanjeeva reddy,s/oPeddha veerananarappa reddy,	12.0	10.0	light	Open well	13	With in the field	subme rsible	10/8 stage	73	8.3

	Naarpala(v)&(mandal), Ananthapuram (Dist).										
16	Sri Bolla Shankar reddy, s/o Ram reddy, Dhayyala kunta palli(v), Bukka raya samudhram(mandal), Ananthapuram (Dist).	5.8	4.0	light	Bore well	76	With in the field	subme rsible	6.0/5 stage	45	4.0
17	Thota palli Saidhulu, s/o Veeraiah, Polapalli(v), Chandhampeta(mandal), Nalgonda (Dist).	16.0	8.0	light	Bore well	60	With in the field	subme rsible	5.0/8 stage	73	3.0
18	Sapaavat Balu nayan, s/o Sheethya nayar, Venkata thanda (v), Chandhampeta (mandal),	12.0	8.0	light	Bore well	40	With in the field	subme rsible	5.0/5 stage	45	4.2

	Nalgonda (Dist).											
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S. No.	Name of the farmer & address	CROP DETAILS		SPRINKLER IRRIGATION SYSTEM DETAILS							Remarks By The Farmers	Research scholars observations		
		Type (Kharif)	Extent (ac)	Year of purchase	Type of system	No. of pipes	Size of pipes (mm)	Type of nozzle	No of nozzles	Distance between sprinklers		Pressure at nozzle end(kg/cm ²)	Discharge from nozzle	% of U _C
1	Madavakunta vijaya BhaskarReddy, s/o Timmareddy Inagaluru(v), Thonduru(mandal), Kadapa(Dist.)	Ground nut	2.5	2008	Semi permanent	-	75,25	Impact	8	12	i)no after sale service & guidance from the supplier ii)Improper overlap	0.9	0.3	<85%
2	Goddeti Narayana Reddy s/o pedda Thirupal Reddy	Ground nut	6	2008	Semi permanent	-	75,25	Impact	18	12	i)no after sale service & guidance from the supplier	1.2	0.35	<85%

	Inagaluru(v), Thonduru(mandal), Kadapa(Dist.)										ii)Improper overlap			
3	Aguduru Krishnamurthy s/o Jagannatha Rao Inagaluru(v), Thonduru(mandal), Kadapa(Dist.)	Ground nut	2.5	2008	Semi perman ent	-	75,25	Impact	18	12	i)no after sale service & guidance from the supplier ii)Improper overlap	1.2	0.35	<85%
4	Chappidi Ramana Reddy s/o C.V.Narayana Reddy Ankalamma Guduru(v),Simhadrip uram(mandal), Kadapa(Dist.)	Ground nut	8	2007	Semi perman ent	-	75,25	Impact	24	12	i)no after sale service & guidance from the supplier ii)Improper overlap	1.1	0.3	<85%
5	Mode Munyanaik	Ground nut	5	2007	portabl e	50	75	Impact	15	6	i)Leakages from	0.9	0.28	<85%

	s/o Dhanseemanna Nagulaguddam Thanda(V), Singanamala(mandal ,Ananthapuru(Dist.)										couplers iii)troubles ome for shifts iv)Much time consuming to cover total area			
6	Mode Badyanaik s/o Bhavyanaik Nagulaguddam Thanda(V), Singanamala(mandal , Ananthapuru(Dist.)	Ground nut	6	2006	Portabl e	25	75	Impact	16	6	i)Leakages from couplers iii)troubles ome for shifts iv)Much time consuming to cover total area	0.9	0.28	<85%
7	Ammaladinne Nallappa s/o Pedda Narappa Nagulaguddam (V), Singanamala(mandal	Ground nut	4	2006	Portabl e	25	75	Impact	10	12	i)Leakages from couplers iii)troubles ome for shifts	1	0.3	<85%

	), Ananthapuru(Dist.)										iv)Much time consuming to cover total area			
8	Poliki Venkatanarayanappa s/o Kullayappa Nagulaguddam (V), Singanamala(mandal) Ananthapuru(Dist.)	Ground nut	2	2007	Portabl e	25	75	Impact	6	12	i)Leakages from couplers iii)troubles ome for shifts iv)Much time consuming to cover total area	0.9	0.28	<85%
9	Sri Challa Naidu, s/o Vobhulesh, Linga reddy palli (v), Sanjeeva puram(po), Batthula palli(m), Ananthapuram(Dist).	Ground nut	8	2003	Portabl e	30	75	Impact	7	12	i)Leakages from couplers iii)troubles ome for shifts iv)Much time consuming to cover total area	1.3	0.35	<85%

10	Sri Challa Naranayana swamy, s/o Vobhulesh, Linga reddy palli (v), Sanjeeva puram(po), Batthula palli(m), Ananthapuram(Dist).	Ground nut	7	2005	Portabl e	40	75	Impact	13	6	i)Leakages from couplers iii)troubles ome for shifts iv)Much time consuming to cover total area	1	0.3	<85%
11	Jakkamputi Praveen, s/o Nagabhushanam, Batthula palli (v)&(m), Ananthapuram (Dist).	Ground nut	3	2007	Portabl e	25	75	Impact	10	12	i)Leakages from couplers iii)troubles ome for shifts iv)Much time consuming to cover total area	1	0.3	<85%
12	Sri Raagechinna Kullayappa, s/o Ranganna,	Ground nut	5	2007	Semi perman ent	-	75,25	Impact	6	12	I)Spare parts are not available & no guidance	1.1	0.4	<85%

	Gummallakunta(v), Batthula palli(m), Ananthapuram (Dist).										from supplier ii)Improper overlap			
13	Sri Varimadugu Nagi Reddy, s/o Malli reddy, Gummallakunta (v), Batthula palli (mandal), Ananthapuram (Dist).	Ground nut	4	2003	Portabl e	20	75	Impact	4	6	i)Leakages from couplers iii)troubles ome for shifts iv)Much time consuming to cover total area	1	0.25	<85%
14	Annagiri Narayana, s/o Pollanna, Mannila(v), Ananthapuram rural(mandal), Ananthapuram (Dist).	Ground nut	3	2007	Portabl e	25	75	Impact	5	12	i)Leakages from couplers iii)troubles ome for shifts iv)Much time consuming to cover	1	0.3	<85%

											total area			
15	Sri Kovvuri Sanjeeva reddy, s/o Peddha veerananarappa reddy, Naarpala(v)&(mandal), Ananthapuram (Dist).	Ground nut	10	2008	Portable	75	75	Impact	18	12	i)Leakages from couplers iii)troublesome for shifts iv)Much time consuming to cover total area	1	0.3	<85%
16	Sri Bolla Shankar reddy, s/o Ram reddy, Dhayyala kuntapalli(v), Bukka raya samudhram(mandal), Ananthapuram (Dist).	Ground nut	4	2008	Portable	25	75	Impact	6	12	i)Leakages from couplers iii)troublesome for shifts iv)Much time consuming to cover total area	1.2	0.4	<85%
17	Thota palli Saidhulu,	Ground nut	8	2006	Portable	50	12	Impact	12	6	i)Leakages from	1.2	0.35	<85%

	s/o Veeraiah, Polapalli(v), Chandhampeta(mandal), Nalgonda (Dist).										couplers iii)troubles ome for shifts iv)Much time consuming to cover total area			
18	Sapaavat Balu nayan, s/o Sheethya nayar, Venkata thanda (v), Chandhampeta (mandal), Nalgonda (Dist).	Ground nut	6	2008	Portabl e	55	75	Impact	8	6	i)Leakages from couplers iii)troubles ome for shifts iv)Much time consuming to cover total area	1	0.28	<85%

