Performance Evaluation of Locally Manufactured pressurized Irrigation

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Abstract

Rainguns are large rotary sprinklers similar in many ways to the small ones. They are usually mounted on three-leg stands, sledges or wheeled carriages, which can be adapted to suit the various furrow and row spacing and crop heights. They are of robust construction to withstand the large forces produced by the high discharge rates and operating pressures. They are of two types: a) swing-arm Raingun; and b) water-turbine Raingun.

Economics of locally manufactured Raingun sprinkler irrigation systems must be seen from two standpoints. Firstly, these systems and innovative adaptations must be cost-effective in the existing framework of the farmers' investment capacity in terms of the capital investments. Secondly, these systems and innovative adaptations must be cost-effective in terms of water and energy efficiency.

Two Raingun sprinkler irrigation systems were installed in the Mona SCARP area of Bhalwal, Sargodha having thin layer of fresh groundwater overlain by the brackish groundwater. There is shortage of fresh groundwater; therefore, farmers' are interested in conjunctive use of water (rainfall, canal water and groundwater). For this purpose, two farmers, in Chak #6ML and Thatti Noor villages were selected to install the skimming dugwells and Raingun sprinkler irrigation systems.

The unit cost can be reduced by 28% by changing the design from complete irrigation to supplemental irrigation. The pressure variations in the two systems installed in the Mona SCARP was 3-10%. The coefficient of uniformity of the Raingun varied between 78 to 91 % with pressure range of 30-40 m and nozzle sizes of 6 to 12 mm diameter. The evenness of water distribution under sprinkler irrigation can be seriously affected by wind and operating pressure. To reduce the effect of wind, the setting distance of Raingun sprinklers can be brought closer together. Thus reasonably high value of uniformity coefficient can be obtained through overlapping by adjusting the space between two Raingun sprinklers. Overlapping of 25% is essential to have better uniformity in water distribution.

Based on the performance evaluation of the Raingun sprinkler irrigation system it is necessary to develop standards for the manufacturers', so that they can use these standards as specifications for the manufacturing of Raingun sprinkler irrigation systems. Therefore, efforts should be made to minimize the pressure requirement to reduce the size of the pumping system leading to minimize the energy requirement. The layout of the Raingun sprinkler irrigation should be designed in such a way that the

coefficient of uniformity is optimised. This would help to improve the water use efficiency.

INTRODUCTION

Raingun Sprinkler Irrigation

Rainguns are large rotary sprinklers similar in many ways to the small ones. They are usually mounted on three-leg stands, sledges or wheeled carriages, which can be adapted to suit the various furrow and row spacings and crop heights. They are of robust construction to withstand the large forces produced by the high discharge rates and operating pressures. They are of two types: a) swing-arm Raingun; and b) water-turbine Raingun.

The swing-arm Raingun operates in a similar manner to the small rotary sprinkler. It rotates by means of a drive spoon on the end of a swing-arm, which is free to move up and down. The spoon is shaped so that water jet pushes the swing-arm downwards out of the flow. At the same time it is pushed sideways causing the Raingun to turn slightly. Once clear of the flow the swing arm is so balanced that it returns to interrupt the jet again. The Raingun then receives another sideways impulse. This action is repeated in a steady beating motion causing the Raingun to slowly rotate. The spoon also helps to breakup the water into fine droplets. The speed at which the Raingun rotates is controlled by the angle of the drive spoon and an adjustable friction brake. One complete revolution can take from 2 to 5 minutes (Kay 1983).

Rainguns can irrigate through a full circle but sector Rainguns that irrigate part of a circle are most common and preferred by farmers. When a sector Raingun reaches the end of its circular path it reverses rapidly again to the beginning. This is achieved by a series of smooth cams known as sector stops. When nearing the end of its path the cam roller rides on to the sector stop and engages the reversing arm from the jet. The Raingun is then set to start irrigation again. The positions of the sector stops are adjustable so that any size of circular arc can be irrigated (Kay 1983).

A rapid return of the Raingun at the end of a sector avoids un-necessary wastage of water but can create problems by over-riding the disengaging stop. In order to produce a sprinkler pattern, which is symmetrical, the disengaging stop is sometimes positioned to allow for the inertia for the Raingun. However, the speed of the gun reversing action is adjustable and should be checked and reset if seen to be very forceful (Kay 1983).

The water-turbine Raingun is similar in appearance to the swing-arm Raingun but moves in a smooth continuous manner rather than in a series of small jerks. This is because driven by small water turbine powered from the main jet or from a smaller nozzle close by. Rotation is achieved by means of a rack and pinion drive connected to the turbine through a small gearbox. The speed at which the Raingun rotates is controlled by the speed of the turbine wheel (Jensen 1981).

Locally Manufactured Raingun Sprinkler Irrigation Systems

Sprinkler irrigation is being introduced in several demonstration plots in the country. Furthermore, progressive farmers have imported sophisticated systems such as centre pivots and linear move sprinkler machines during 80s. The conventional sprinkler irrigation systems are capital intensive. Therefore, some modifications were needed to suit the socio-economic conditions and physical requirements in Pakistan (WRRI 1992).

The sprinkler system can be used with gravity flow where hydraulic head is available, which will reduce the initial cost. Such locations are available in Northern Areas, NWFP and Balochistan. Furthermore, these systems are suitable for areas where streamsize is very small and surface irrigation is not possible. Such locations are available in areas having limited well yields in mountainous and Barani regions and in the Indus basin having very thin layer of fresh groundwater overlain the brackish groundwater (Ahmad and Hussain 1987; Ahmad et al. 2000; WRRI 1992).

Most of the system components of solid-set, hand move and Raingun sprinklers have been successfully manufactured in Pakistan, except the cost effective aluminium pipes would need to be imported for specialized systems. The Water Resources Research Institute (WRRI), National Agricultural Research Centre (NARC), Islamabad in collaboration with MECO Pvt. Ltd., Lahore developed a complete range of Raingun sprinkler irrigation systems using locally available materials and technology. The high-pressure low-density polyethylene pipes with black carbon and UV stabilizers were produced in collaboration with Griffon Industrial Corporation, Lahore. These are now available in 13, 25, 50, 75 and 100 mm diameters, which can be used for pressures upto 84 m. Recently, the low-pressure systems are being designed and installed by farmers due to the rise in electricity tariff and diesel prices. The estimated installed cost of semi-solidset Raingun sprinkler irrigation systems is in the range of Rs. 25,000-40000 per ha for a system of atleast 4 ha using electric or diesel operated pumping systems.

Economics of Raingun Sprinkler Irrigation Systems

Economics of locally manufactured Raingun sprinkler irrigation systems must be seen from two standpoints. Firstly, these systems and innovative adaptations must be cost-effective in the existing framework of the farmers' investment capacity in terms of the capital investments. Secondly, these systems and innovative adaptations must be cost-effective in terms of water and energy efficiency (Irrigation Age 1977; Walker 1980).

These two elements were given due consideration while indigenizing the Raingun sprinkler irrigation system components in Pakistan. In fact there is a need to have trade-off between the two objectives of economics to have system fairly cost-effective in capital investment and fairly cost-effective in water and energy efficiency. A balance between the two is the approach, which will work in Pakistan.

Performance of Raingun Sprinkler Irrigation Systems

The evenness of water distribution can be seriously affected by wind and operating pressure. Spray from Raingun sprinklers is relatively of larger discharges compared to the standard sprinklers. However, it is easily blown by wind and this can distort wetting patterns and upset irrigation uniformity. To reduce the effect of wind, the setting distance of Raingun sprinklers can be brought closer together.

Although 5 m/s is only thought of as gentle breeze, it will seriously disrupt the operation of a Raingun. Rainguns need to operate very close together under these conditions to distribute water evenly. In prevailing wind conditions the designer will normally position the lateral at right angles to the wind direction and reduce the Raingun spacing along the lateral line (Kay 1983).

A Raingun sprinkler performs best at a given pressure, which is normally specified by the manufacturer. If the pressure is substantially above or below the recommended value then the distribution of water can be quite different from the normal distribution. If the pressure is substantially above and below the recommended pressure, then in both the cases the throw is reduced. Both these patterns are quite different from the normal triangular distribution and it is obvious that patterns such as these will not produce a uniform irrigation (Kay 1983).

Raingun Sprinkler Irrigation for Indus Basin

Raingun sprinkler irrigation systems can also be used in the Indus basin for efficient application of smaller stream size of even less than 3 lps pumped from the skimming wells. However, to minimise the input of groundwater and to maintain low cost of irrigation, it is necessary to integrate conjunctive use of rainfall, surface water and groundwater. The design and operation of irrigation systems will be based on the concept of management strategies considering the conjunctive water use. Therefore, design of pressurized irrigation systems should be made considering these concepts (Ahmad *et al.* 2000).

The present study is based on the concept of conjunctive use of rainfall, canal water and groundwater with a view to design Raingun sprinkler systems to evaluate the cost and performance of the systems under the concept of supplemental irrigation linked with the use of groundwater. Furthermore, this concept is in co-existence with the use of skimmed water, where discharges are much less than the traditional tubewells.

MATERIALS AND METHODS

Study Area

Two Raingun sprinkler irrigation systems were installed at farmers' fields in the Mona SCARP area of Bhalwal, Sargodha having thin layer of fresh groundwater overlain by the brackish groundwater. There is shortage of fresh groundwater; therefore, farmers are interested in conjunctive use of water (rainfall, canal water and groundwater). For this purpose, two farmers, in Chak #6ML and Thatti Noor villages, were selected to install the skimming dugwells and Raingun sprinkler irrigation systems.

Selection of Farmers and Design of Raingun Sprinkler Irrigation Systems

Two Raingun sprinkler irrigation systems were designed with an objective to test the concept of partial (supplemental) and complete irrigation concepts. The supplemental or partial irrigation system was designed to provide groundwater in addition to the rainfall and canal water availability. Therefore, the supplemental irrigation would help to reduce the unit cost of the Raingun sprinkler irrigation system.

Supplemental Irrigation System at Chak #6ML

In Chak #6ML, Ahmad Bakhsh Farm was selected for the installation of small-size Raingun sprinkler irrigation system on the dugwell. This system was designed to operate single-Raingun for small-size farms using a concept of supplemental irrigation. The designed operational time of 15 hours was used with overlapping of 25%. Peak designed supplemental water requirement of 3-mm was used.

Farmer's abandoned dugwell was renovated, which was constructed in 1930s. The dugwell depth is 18.24 m and the inner diameter of the dugwell is around 1.52 m. A high pressure pumping system having discharge of 3 lps and pressure head of 60 m was installed at the renovated well. Diesel-operated prime mover of 8 hp was used to power the pumping system. Two manifolds each with 50 mm diameter were laid out having lengths of 176 m and 264 m. Raingun model $PY_{1\text{-}30}$ with nozzle size of 12 mm diameter was used. The summary of design computations of Raingun sprinkler irrigation system installed on 5.3 ha area is presented in **Appendix I**. The command area can be increased to 7 ha if the peak operational time is increased to 20 hours. This is important to improve economics of the system.

Complete Irrigation System at Village Thatti Noor

In Thatti Noor village, Qadir Farm was selected for the installation of medium-size Raingun sprinkler irrigation system. This system was designed to operate 3 Rainguns for medium-size farms using a concept of complete irrigation. The designed operational time of 12 hours was used with overlapping of 25%. Peak designed water requirement of 5-mm was used.

A dug-bore well was constructed and lined using the pre-cast concrete rings. The technology of dug-bore well is attractive to reduce the digging cost and to induce higher recharge. Bore is needed in the saturated zone because the digging of dugwell in the saturated zone after a depth of 3 m is cumbersome and costly. The dugwell total depth is 5.63 m and the inner diameter of the dugwell is around 1.52 m. A bore of 3.52 m was made from a depth of 5.63 to 9.15 m. A high pressure pumping system having discharge of 8.2 lps and pressure head of 60 m was installed on the dug-bore well. Diesel operated prime mover of 18 hp was used to power the pumping system. Two manifolds were designed 1st having 75 mm inner diameter and 2nd with 50 mm inner diameter low-density polyethylene (LDPE) pipe. The lengths of 1st and 2nd manifolds are 250 and 364 m, respectively. The summary of design computations of Raingun sprinkler irrigation system installed on 5.7 ha area is presented in **Appendix II**. The command area can be increased to 9.5 ha if the peak operational time is increased to 20 hours.

Materials Used and Systems' Cost

Supplemental Irrigation System at Chak #6ML

Diesel operated pumping system was coupled with suction line of 63.75 mm inner diameter of galvanized iron pipe. The 51 mm inner diameter galvanized iron pipe was also used for delivery of water to the manifolds. The LDPE pipe of 50 mm inner diameter was used for manifolds. All the connections used were made of galvanized iron or metal alloys. The hydrants for water outlets were constructed using galvanized iron pipe of 51 mm diameter. The cost estimates of Raingun sprinkler irrigation system installed at the Ahmad Bakhsh Farm, Chak #6ML are presented in **Appendix III**.

Complete Irrigation System at Village Thatti Noor

Diesel operated pumping system was coupled with suction line of 63.75 mm inner diameter of galvanized iron pipe. The 51 mm inner diameter galvanized iron pipe was used for delivery of water to the manifolds. The LDPE pipe of 75 and 50 mm inner diameter were used for mainline and manifolds. All the connections used were made of galvanized iron or metal alloys. The hydrants for water outlets were constructed using galvanized iron pipe of 51 mm diameter. The cost estimates of Raingun sprinkler irrigation system installed at the Qadir Farm, Thatti Noor village are presented in **Appendix IV**.

Performance Evaluation

Performance Parameters

The performance parameters selected for evaluation of Raingun sprinkler irrigation system are as under:

1. Operating pressure of Raingun at various hydrants installed for connecting laterals and the Raingun;
2. Discharge of Raingun installed at various hydrants;
3. Uniformity coefficient.

Raingun with different sizes of nozzles was operated for one-hour duration under selected range of pressures. The sprinkled water was collected in the catch cans and depth of water was measured after the closure of the

Raingun. The coefficient of uniformity of the Raingun was estimated using the following relationship (Christiansen 1942):

$$C_u = [1 - \{(|\sum X_i - X_{av}|) / nX_{av}\}] * 100$$

where

C_u	=	Coefficient of uniformity, %;
X_i	=	Depth of water stored in the ith catch can, mm;
n	=	Total number of catch cans having water or number of observations; and
X_{av}	=	Average depth of water collected in catch cans, mm.

Supplemental Irrigation System at Chak #6ML

Performance of single-Raingun sprinkler irrigation system was evaluated at the Ahmad Bakhsh Farm of Chak #6ML. At this farm, the Raingun sprinkler irrigation system was evaluated by operating single Raingun with nozzle of 12 mm diameter. Evaluation was made at each hydrant to document the system's performance.

Complete Irrigation System at Village Thatti Noor

At Qadir's Farm in the Thathi Noor village, the system was evaluated at different hydrants. Discharge, pressure and covered area were measured at 60% engine throttle. Data of selected parameters were measured while operating two and three Rainguns with different sizes of Raingun nozzles.

RESULTS AND DISCUSSIONS

System Layout and Cost

Supplemental Irrigation System at Chak #6ML

In Chak #6ML Ahmad Bakhsh Farm was selected to install small-size Raingun sprinkler irrigation system, where discharge is sufficient to operate single Raingun. The system layout consisted of two manifolds of 50 mm inner diameter pipe of LDPE. Six double and two single hydrants were installed (Figure 1). The cost of pumping system with attachments for suction and delivery line was Rs. 21,133, which accounts for 29% of the total material cost. The cost of manifolds was Rs. 44,102, which accounts for 60% of the total material cost. The cost of other materials including hydrants, connections and gate valves was Rs. 8070, which accounts for 11% of the material cost. Thus the major cost is for manifolds and pumping system and related attachments. The cost of installation of Raingun sprinkler irrigation system was around Rs. 13,000. Thus the total cost of system and installation was Rs. 86,305. The average cost per ha was Rs. 16,284. Therefore, the unit cost would range between Rs.16,000 to 17,000 (Table 1).

The unit cost was reduced almost by 28% by changing the concept from complete irrigation to supplemental irrigation. This was a good achievement for the canal command areas, where the peak crop water requirement from Raingun sprinkler irrigation is reduced due to the conjunctive use of rainfall, canal water and groundwater.

Complete Irrigation System at Village Thatti Noor

In Thatti Noor village Qadir Farm was selected to install medium-size Raingun sprinkler irrigation system, where discharge was sufficient to operate 3 Rainguns depending on the availability of water from the dugwell. In fact the system was designed to operate three Rainguns, but due to shortage of water in the dugwell because of continued drought two Rainguns were appropriate to operate. The system layout consisted of two manifolds of 75 and 50 mm inner diameter of LDPE pipe. Six double and six single hydrants were installed (Figure 2). The cost of pumping system with attachments for suction and delivery line including foundation was Rs. 34,347, which accounts for 30% of the total material cost. The cost of manifolds was Rs. 67,615, which accounts for 59% of the total material cost. The cost of other materials including hydrants, connections and gate valves was Rs. 12,980, which accounts for 11% of the material cost. Thus the major cost is for manifolds and pumping system and related attachments. The cost of installation of Raingun sprinkler irrigation system was around Rs. 14,000. Thus the total cost of system and installation was Rs.1,28,942. The average cost per ha was Rs. 22,621. Therefore, the unit cost would range between Rs.22,000 to 23,000 (Table 1).

The unit cost was 39% more than the other farm, where system was designed for supplemental irrigation. This increase was due to the increase in the peak crop water requirement for the Raingun sprinkler irrigation system. However, the system size can be increased for conditions of supplemental irrigation.

System Performance

Discharge and Pressure Variations

Supplemental Irrigation System at Chak #6ML

The discharge and pressure of Raingun sprinkler measured at each hydrant of the system installed at Chak #6ML, Bhalwal is given in Table 2. The nozzle size of 12 mm diameter was used. The pressure at Raingun ranged between 39.9 m to 37.1 m with an average of 38.8 m. The pressure variations were ±3.6 percent, which is extremely low and thus the system performance in terms of pressure variations was within the permissible limits. The discharge of Raingun ranged between 2.69 lps to 2.58 lps with an average of 2.65 lps. The discharge variations were ±2.1 percent.

Complete Irrigation System at Village Thatti Noor

The performance evaluation of Raingun system at the Thatti Noor Farm was conducted under two sets of pressure conditions, when two Rainguns were used. In the first setting, the pressure at the pumping system was maintained at 35 m head, whereas in the second setting the pressure at pumping system was maintained at 28 m. The two sets of pressure conditions would help to evaluate the system in terms of pressure range instead of a fixed pressure.

For the first setting, the pressure at the pumping system was maintained at 35 m. The discharge and pressure of Raingun sprinkler measured at each hydrant of the system is given in Table 3. The nozzle size of 10 mm diameter was used. The pressure at Raingun ranged between 35.0 m to 30.8 m with an average of 33.8 m. The pressure variations were ±6.2 percent, which is reasonably low and thus the system performance in terms of pressure variations was within the permissible limits. The discharge of Raingun ranged between 1.92 lps to 1.80 lps with an average of 1.89 lps. The discharge variations were ±3.2 percent.

For the second setting, the pressure at the pumping system was maintained at 28 m. The discharge and pressure of Raingun sprinkler measured at each hydrant is given in Table 4. The nozzle size of 10 mm diameter was used. The pressure at Raingun ranged between 28.0 m to 22.4 m with an average of 26.1 m. The pressure variations were ±10.7 percent, which is reasonably low and thus the system performance in terms of pressure variations was within the permissible limits. The discharge of Raingun ranged between 1.73 lps to 1.58 lps with an average of 1.68 lps. The discharge variations were ±4.5 percent.

The pressure variations were ±3.6 and 6.2%, which is extremely low and thus the system performance in terms of discharge variations was within the permissible limits. This was mainly due to appropriate size of the Raingun nozzle, layout of the manifold, and the optimal range of Raingun pressure (30-40 m). The pressure variations increased to ±10.7%, when the pressure of the pump dropped to 28 m and pressure at Raingun was in the range of 22-28 m. Thus the Raingun pressure must be maintained between 30-40 m.

Radius of Coverage as Affected by Water Level in the Dugwell

Supplemental Irrigation System at Chak #6ML

Raingun sprinkler with 12 mm diameter nozzle size was used to estimate radius of coverage as affected by time and pressure. In fact there was lowering of water table in the dugwell up to 80 minutes from the start of the pumping. The depletion in dugwell water level was 1.38 m in 80 minutes and afterwards the water level in the dugwell got stabilized. The pressure at Raingun ranged between 39.9 m to 37.1 m with an average of 38.4 m. The pressure variations were ±3.6 percent, which is reasonably low and thus the system performance in terms of pressure variations was within the permissible limits. The radius of coverage of Raingun ranged between 24 m to 21 m with an average of 22.1 m (Table 5). The variations in radius of coverage were ±6.8 percent, which is reasonably low and thus the system performance in terms of area covered was within the permissible limits. The variations in Raingun radius of coverage were more than Raingun pressure, which is a good indication of the sensitivity of area of coverage as affected by pressure variations.

The radius of coverage is not the appropriate performance parameter; therefore this information must be used in estimating the area of coverage. The area of coverage at 24 m radius was 1810 m^2, whereas it was reduced to 1385 m^2 with reduction in radius of coverage to 21 m. The average area of coverage was 1534 m^2. Thus the variation in area of coverage from the average was ±13.8 percent, which is a concern. However, it will not affect the distribution of water except overlapping has to be adjusted accordingly.

Pressure Variations as Affected by Water Level in the Dugwell

For the Qadir Farm at Thatti Noor village, the evaluation was made under three settings in terms of Raingun positions at different hydrants. In all the three setting, three Rainguns were used to evaluate the performance in terms of water level in the dug-bore well and pressure variations.

First Setting of Rainguns

Three Rainguns were installed at hydrants # 1, 6 and 12 located at a distance of 20, 225 and 351 m from the pumping system, respectively. Raingun nozzle diameter of 8 mm was used. The water level in the dugwell stabilized at 5.62 m after 50 minutes of the operation of the pumping system. The pressure variation since the start of the pumping ranged between 40.6 m and 36.4 m at hydrants 1 and 12, respectively. The average pressure was 38.2 m. The pressure variation was ±5.5 percent (Table 6).

Second Setting of Rainguns

Three Rainguns were installed at hydrants # 1, 2 and 7 located at a distance of 20, 60 and 142 m from the pumping system, respectively. Raingun nozzle diameter of 8 mm was used. The water level in the dugwell stabilized at 5.61 m after 50 minutes of the operation of the pumping system. The pressure variation since the start of the pumping ranged between 40.6 m and 35.0 m at hydrants 1 and 7, respectively. The average pressure was 37.6 m. The pressure variation was ±7.4 percent (Table 7).

Third Setting of Rainguns

Three Rainguns were installed at hydrants # 3, 6 and 12 located at a distance of 100, 225 and 351 m from the pumping system, respectively. Raingun nozzle diameter of 8 mm was used. The water level in the dugwell stabilized at 5.61 m after 40-50 minutes of the operation of the pumping system. The pressure variation since the start of the pumping ranged between 40.6 m and 35.7 m at hydrants 3 and 12, respectively. The average pressure was 37.9 m. The pressure variation was ±6.5 percent (Table 8).

The evaluation of the three settings of the Raingun sprinklers indicated that the pressure variations varied between ± 5.5 to 7.4 %, which were within the permissible limits even during the transient state. The discharge variability would be in the order of ± 2.75 to 3.7%, which is also within the permissible range.

Performance of Raingun as affected by the Dugwell Yield

Supplemental Irrigation System at Chak #6ML

The operation of Raingun sprinkler at the dugwell installed at the Ahmad Bakhsh Farm at Chak #6ML indicated that dugwell could provide sustainable yield after 80 minutes. After stabilizing the water level in the dugwell, pressure and radius of coverage was also stabilized. Therefore, these pressures and radius of coverage should be used for the purpose of operation of the Raingun sprinkler. The constant pressure of 37 m can be maintained at the Raingun with constant radius of coverage of 21 m. Therefore, the constant area of coverage by the Raingun would be 1385 m^2 (Table 5). The system performed reasonably well as per design specifications primarily due to the sustained well yield at water depletion level of 1.38 m from surface of the well.

The field evaluation indicated that Raingun system installed on dugwells should be evaluated to find the appropriate levels for Raingun pressure, discharge, radius of coverage, and water level in the dugwell. If the water level in the dugwell drops more than 6 m, the discharge would be reduced tremendously. Thus draw down in the dugwell should be less than the permissible suction to attain the designed discharge.

Complete Irrigation System at Village Thatti Noor

The complete irrigation system was designed under two sets of Raingun settings. In the 1st set, two Rainguns were used with nozzle size of 10 mm diameter. The pressure variation was ±6.2% at pumping pressure of 35 m, whereas it was increased to ±10.7% with the reduced pumping pressure of 28 m. In the 2nd set, three Rainguns were used with nozzle size of 8 mm diameter. The pressure variation was ±5.5 to ±7.4 % under three settings of the Raingun positions. The stabilized pumping pressure with stabilized water level in the dugwell was around 40 m. The conclusion is that both sets of Rainguns (2 or 3) can be used with reasonable level of performance.

The details of three settings each with three Rainguns using 8 mm diameter nozzle are as under:

First Setting of Rainguns: Three Rainguns were installed at hydrants # 1, 6 and 12 located at a distance of 20, 225 and 351 m from the pumping system, respectively. Raingun nozzle diameter of 8 mm was used. The water level in the dugwell stabilized at 5.62 m after 50 minutes of the operation of the pumping system. The pressure variation at the start of the pumping ranged between 40.6 m and 37.8 m at hydrants #1 and 12, respectively. The average pressure was 39.2 m. The pressure variation was ±3.6. After stabilizing the water level in the dugwell, the pressure variation ranged between 38.5 and 36.4 m at hydrants #1 and 12, respectively. The average pressure was 37.6 m. The percent variation in pressure was ±2.8. The variation in Raingun pressure was reduced after the stabilization of the water level in the dugwell (Table 6).

Second Setting of Rainguns: Three Rainguns were installed at hydrants # 1, 2 and 7 located at a distance of 20, 60 and 142 m from the pumping system, respectively. Raingun nozzle diameter of 8 mm was used. The water level in the dugwell stabilized at 5.61 m after 50 minutes of the operation of the pumping system. The pressure variation at the start of the pumping ranged between 40.6 m and 38.5 m at hydrants # 1 and 7, respectively. The average pressure was 39.7 m. The pressure variation was ±2.6. After stabilizing the water level in the dugwell, the pressure variation ranged between 38.5 and 35.0 m at hydrants 1 and 7, respectively. The average pressure was 36.9 m. The percent variation in pressure was ±4.7 (Table 7).

Third Setting of Rainguns: Three Rainguns were installed at hydrants number of 3, 6 and 12 located at a distance of 100, 225 and 351 m from the pumping system, respectively. Raingun nozzle diameter of 8 mm was used. The water level in the dugwell stabilized at 5.61 m after 40-50 minutes of the operation of the pumping system. The pressure variation at the start of the pumping ranged between 40.6 m and 37.1 m at hydrants #3 and 12, respectively. The average pressure was 38.9 m. The pressure variation was ±4.5. After stabilizing the water level in the dugwell, the pressure variation ranged between 38.5 and 35.7 m at hydrants #3 and 12, respectively. The average pressure was 37.1 m. The percent variation in pressure was ±3.8 percent. The pressure variation was reduced after stabilization of the water level in the dugwell (Table 8).

Coefficient of Uniformity Under Various Pressure

For Raingun sprinkler irrigation system, the last quarter is overlapped to obtain better uniformity of water distribution. Therefore, the spacing between two sprinklers is kept equal to the effective diameter of coverage of the Raingun sprinkler. The coefficient of uniformity of the Raingun sprinklers was determined at the effective diameter of coverage i.e. up to third quarter. The coefficients of uniformity of the Raingun sprinkler as affected by effective diameter of coverage, nozzle sizes and pressure are presented in Table 9.

Nozzle Size of 6 mm Diameter

For the nozzle size of 6 mm diameter, the maximum coefficient of uniformity of 86.5% was observed at pressure head of 28 m. The effective diameter of coverage was 27 m, which represents the 75% of the potential diameter of coverage. However, with overlapping of 25% same level of uniformity can be achieved with potential diameter. Thus pressure head of 30 m is recommended with nozzle size of 6 mm diameter.

Nozzle Size of 8 mm Diameter

For the nozzle size of 8 mm diameter, the maximum coefficient of uniformity of 86.3% was observed at pressure head of 28 m. The effective diameter of coverage was 31 m, which represents the 75% of the potential diameter of coverage. However, with overlapping of 25% same level of uniformity can be achieved with potential diameter. Thus pressure head of 30 m is recommended with nozzle size of 8 mm diameter.

Nozzle Size of 10 mm Diameter

For the nozzle size of 10 mm diameter, the maximum coefficient of uniformity of 90.8% was observed at pressure head of 39 m. The effective diameter of coverage was 33 m, which represents the 75% of the potential diameter of coverage. However, with overlapping of 25% same level of uniformity can be achieved with potential diameter. Thus pressure head of 30-40 m is recommended with nozzle size of 10 mm diameter.

Nozzle Size of 12 mm Diameter

For the nozzle size of 12 mm diameter, the maximum coefficient of uniformity of 78.1% was observed at pressure head of 32 m. The effective diameter of coverage was 39 m, which represents the 75% of the potential diameter of coverage. However, with overlapping of 25% same level of uniformity can be achieved with potential diameter. Thus pressure head of 30-40 m is recommended with nozzle size of 12 mm diameter.

The coefficient of uniformity of the Raingun varied between 78 to 91 % with pressure range of 30-40 m and nozzle sizes of 6 to 12 mm diameter. Thus reasonably high value of uniformity coefficient can be obtained through overlapping by adjusting the space between two Raingun sprinklers. Walker (1980) recommended that uniformity coefficient should be in the range of 70 to 80 %. Jensen (1981) recommended that coefficient of uniformity should be more than 80% to justify the investments made in sprinkler irrigation. However, it is difficult to have higher uniformity coefficient without overlapping, as uniformity of Raingun sprinklers is always less than the smaller sprinklers.

Needed Modifications and Adaptations

The economics of Raingun sprinkler irrigation systems indicated that for the Indus basin, these systems must be designed considering the conjunctive use of rainfall, canal water and groundwater. Thus cost of the system can be reduced by 28% just by changing the concept of complete irrigation to supplemental irrigation. This demands that the peak demand water requirement must be changed from 5 mm/day to 3 mm/day or even less. Furthermore, the peak operational time should also be changed to 20 hours to reduce the size of the prime mover and the pump.

The Indus basin is also going to experience the water crises due to increase in demand among the competing water users' and the conflicting objectives. Therefore, sprinklers should be used for vegetables, fodders and field crops, whereas for orchards modified hose-fed system can be used. These systems have already been designed and installed at farmers fields in Khanpur and Haripur areas for the matured orchards, which were established originally under flood irrigation and the rooting pattern is extensive.

Needed Refinement in Design and Manufacturing of Systems' Hardware

Based on the performance evaluation of the Raingun sprinkler irrigation systems it is necessary to develop standards for the manufacturers, so that they can use these standards as specifications for the manufacturing of Raingun sprinkler irrigation systems. There are two major objectives of manufacturing and designing any Raingun sprinkler irrigation system. These include water and energy efficiency and cost-effectivity. Therefore, efforts should be made to minimize the pressure requirement to reduce the size of the pumping system and to minimize the energy requirement. The layout of the Raingun sprinkler irrigation should be designed in such a way that the coefficient of uniformity is optimized. This would help to improve the water use efficiency.

The recommended manufacturers' specifications and design parameters are presented in Table 10. This table provides specifications for the whole range of Rainguns suitable for very small to large farms.

CONCLUSIONS

1. The design and performance evaluation of the Raingun sprinkler irrigation system installed at Bhalwal, Sargodha indicated that the system cost can be reduced by 28% just by changing the design concept from complete irrigation to partial or supplemental irrigation. This is valid for the Indus basin, where concept of conjunctive use of water (rainfall, canal water and groundwater) is practiced.

2. The operational time of Raingun sprinkler irrigation system at peak demand was taken 12-15 hours, which can be increased to 20 hours for further reduction in cost. However, it would depend on the limitations of suction and lowering of water in the dugwell.

3. The level of water in the dugwell is an essential criterion for the design and performance of the system. Although the permissible limit for suction with centrifugal pumps is 6 m but the high-pressure pump performs better if the suction is less than 6 m. Therefore, extra care must be made while designing the pumping systems for Raingun sprinkler irrigation. Under conditions of extreme suction of around 6 m or more, the designed discharge of Raingun with 12 mm diameter nozzle was reduced to the point that either two

Rainguns of 10 mm diameter nozzle or three Rainguns of 8 mm diameter nozzle could be operated. The system was originally designed for three Rainguns with 12 mm diameter nozzle.

4. The important conclusion is that centrifugal pump based Raingun sprinkler irrigation systems should be designed for single Raingun with 12 mm diameter nozzle for sustained pumping and longer operational time for irrigation.
5. The pressure variations ranged between ±3 to ±10%, which is reasonable to have higher uniformity in water distribution (around 80% or more).
6. Another important conclusion is that the performance of locally made Raingun sprinkler irrigation systems is reasonably high at higher pressures of 30-40 m. However, it will reduce significantly if the pressure drops below 20 m.
7. Based on the limitations of the centrifugal pumps and the problem associated with lowering of water table in dugwells, there is a need to design and develop low-cost submersible pumps based Raingun sprinkler irrigation systems.

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Table 1 Cost of raingun sprinkler irrigation systems installed at two selected farms in Mona SCARP, Bhalwal, Sargodha Pakistan.

System Components	Cost (Rs.) (Percent of Total)	
	Allah Bakhsh Farm	Qadir Farm
Pumping System, Suction and Delivery lines and Foundation	21133 (29)	34347 (30)
Manifold #1	19311 (26)	33140 (29)
Manifold #2	24791 (34)	34475 (30)
Other Materials	8070 (11)	12980 (11)
Total Material Cost	73305	114942
Total Installation Cost	13,000	14,000
Total Cost	86,305	1,28,942
Average cost per ha	16,284	22,621
Cost Range (Rs./ha)	16,000-17,000	22,000-23,000

Table 2. Discharge and pressure of raingun sprinkler at various hydrants using 12 mm diameter nozzle at Chak #6ML, Bhalwal, Sargodha, Pakistan.

Position of Raingun	Distance from Pumping Station (m)	Pressure (m)		Discharge (lps)
		Pumping Station	Raingun	
Hydrant #1	48	41.3	39.9	2.69
Hydrant #2	40	41.3	39.9	2.69
Hydrant #3	142	41.3	39.2	2.66
Hydrant #4	176	41.3	39.2	2.66
Hydrant #5	75	41.3	38.5	2.64
Hydrant #6	150	41.3	38.5	2.64
Hydrant #7	208	41.3	37.8	2.61
Hydrant #8	286	41.3	37.1	2.58
Average			38.8	2.65
Percent Variation			±3.6	±2.1

Table 3. Discharge and pressure of Raingun sprinkler at various hydrants using 10 mm diameter nozzle at Thatti Noor village, Bhalwal, Sargodha, Pakistan.

Position of Raingun #1	Distance from Pumping Station (m)	Pressure (m)		Discharge at Raingun #1 (lps)	Position of Raingun #2
		Pumping Station	Raingun #1		
Manifold #1 (75 mm Diameter Pipe)					
Hydrant #1	20	35	35	1.92	Hydrant #6
Hydrant #2	60	35	35	1.92	Hydrant #6
Hydrant #3	100	35	35	1.92	Hydrant #6
Hydrant #4	140	35	35	1.92	Hydrant #6
Hydrant #5	180	35	35	1.92	Hydrant #6
Hydrant #6	225	35	33.6	1.88	Hydrant #5
Manifold #2 (50 mm Diameter Pipe)					
Hydrant #7	142	35	34.3	1.90	Hydrant #1
Hydrant #8	182	35	33.6	1.88	Hydrant #1
Hydrant #9	222	35	33.6	1.88	Hydrant #1
Hydrant #10	256	35	32.9	1.86	Hydrant #1
Hydrant #11	306	35	31.5	1.82	Hydrant #1
Hydrant #12	351	35	30.8	1.80	Hydrant #1
Average			33.8	1.89	
Percent Variation			±6.2	±3.2	

Table 4. Discharge and pressure of Raingun sprinkler at various hydrants using 10 mm diameter nozzle at Thatti Noor village, Bhalwal, Sargodha, Pakistan.

Position of Raingun #1	Distance from Pumping Station (m)	Pressure (m)		Discharge at Raingun #1 (lps)	Position of Raingun #2
		Pumping Station	Raingun #1		
Manifold #1 (75 mm Diameter Pipe)					
Hydrant #1	20	28	28	1.73	Hydrant #6
Hydrant #2	60	28	28	1.73	Hydrant #6
Hydrant #3	100	28	28	1.73	Hydrant #6

Hydrant #4	140	28	28	1.73	Hydrant #6
Hydrant #5	180	28	28	1.73	Hydrant #6
Hydrant #6	225	28	25.9	1.67	Hydrant #5
Manifold #2 (50 mm Diameter Pipe)					
Hydrant #7	142	28	25.2	1.65	Hydrant #1
Hydrant #8	182	28	25.9	1.67	Hydrant #1
Hydrant #9	222	28	25.9	1.67	Hydrant #1
Hydrant #10	256	28	25.2	1.65	Hydrant #1
Hydrant #11	306	28	23.1	1.60	Hydrant #1
Hydrant #12	351	28	22.4	1.58	Hydrant #1
Average			26.1	1.68	
Percent Variation			±10.7	±4.5	

Table 5. Radius of coverage of the Raingun sprinkler under various pressure heads using 12 mm diameter nozzle, Chak #6ML, Bhalwal, Sargodha, Pakistan.

Time (min)	Depth Depleted (m)	Pressure (m)	Radius of Coverage (m)
10	0.87	39.9	24
20	1.04	39.9	24
30	1.23	39.2	23
40	1.30	39.2	22
50	1.32	38.5	22
60	1.34	38.5	22
70	1.36	37.8	21
80	1.38	37.1	21
90	1.38	37.1	21
100	1.38	37.1	21
Average		38.4	22.1
Percent Variation		±3.6	±6.8

Table 6. Evaluation of first setting of three Raingun sprinklers with nozzle diameter of 8 mm at Qadir Farms, Thatti Noor, Bhalwal, Sargodha, Pakistan.

Time (min)	Depth to Water Table (m)	Pressure (m)		Remarks
		Pumping Station	Raingun	
Raingun at Hydrant #1 and at a distance of 20 m from the pumping system				
0	4.12	42	40.6	2nd and 3rd Rainguns at #6 & #12 hydrants
10	4.95	41.3	39.9	"
20	5.38	41.3	39.2	"
30	5.57	40.6	39.2	"
40	5.61	40.6	39.2	"
50	5.62	39.9	38.5	"
60	5.62	39.9	38.5	"
70	5.62	39.9	38.5	"
Raingun at Hydrant #6 and at a distance of 225 m from the pumping system				
0	4.12	42	39.2	2nd and 3rd Rainguns at #1 & #12 hydrants
10	4.98	42	39.2	"
20	5.46	41.3	38.5	"
30	5.59	41.3	38.5	"
40	5.60	41.3	38.5	"
50	5.61	40.6	37.8	"
60	5.62	40.6	37.8	"
70	5.62	40.6	37.8	"
80	5.62	40.6	37.8	"
Raingun at Hydrant #12 and at a distance of 351 m from the pumping system				
0	4.45	42	37.8	2nd and 3rd Rainguns at #1 & #6 hydrants
10	5.25	42	37.8	"
20	5.59	41.3	37.1	"
30	5.60	41.3	37.1	"

40	5.61	41.3	37.1	"
50	5.62	40.6	36.4	"
60	5.62	40.6	36.4	"
70	5.62	40.6	36.4	"
Average			38.2	
Percent Variation			±5.5	

Table 7. Evaluation of second setting of three Raingun sprinklers with nozzle diameter of 8 mm at Qadir Farms, Thatti Noor, Bhalwal, Sargodha, Pakistan.

Time (min)	Depth to Water Table (m)	Pressure (m)		Remarks
		Pumping Station	Raingun	
Raingun at Hydrant #1 and at a distance of 20 m from the pumping system				
0	3.94	42	40.6	2nd and 3rd Rainguns at #2 & #7 hydrants
10	4.87	41.3	39.9	"
20	5.38	40.6	39.2	"
30	5.58	39.9	39.2	"
40	5.59	39.2	38.5	"
50	5.61	39.2	38.5	"
60	5.61	39.2	38.5	"
70	5.61	39.2	38.5	"
80	5.61	39.2	38.5	"
Raingun at Hydrant #2 and at a distance of 60 m from the pumping system				
0	3.94	42	39.9	2nd and 3rd Rainguns at #1 & #7 hydrants
10	4.87	41.3	39.2	"
20	5.38	40.6	38.5	"
30	5.58	39.9	37.1	"
40	5.59	39.2	37.1	"
50	5.61	39.2	37.1	"
60	5.61	39.2	37.1	"
70	5.61	39.2	37.1	"

80	5.61	39.2	37.1	"
Raingun at Hydrant #7 and at a distance of 142 m from the pumping system				
0	3.94	42	38.5	2nd and 3rd Rainguns at #1 & #2 hydrants
10	4.87	41.3	37.8	"
20	5.38	40.6	37.1	"
30	5.58	39.9	36.4	"
40	5.59	39.2	35	"
50	5.61	39.2	35	"
60	5.61	39.2	35	"
70	5.61	39.2	35	"
80	5.61	39.2	35	"
Average			37.6	
Percent Variation			±7.4	

Table 8. Evaluation of third setting of three Raingun sprinklers with nozzle diameter of 8 mm at Qadir Farms, Thatti Noor, Bhalwal, Sargodha, Pakistan.

Time (min)	Depth to Water Table (m)	Pressure (m)		Remarks
		Pumping Station	Raingun	
Raingun at Hydrant #12 and at a distance of 351 m from the pumping system				
0	4.13	42	37.1	2nd and 3rd Rainguns at #3 & 6 hydrants
10	4.96	42	37.1	"
20	5.39	41.3	37.1	"
30	5.58	41.3	36.4	"
40	5.61	41.3	36.4	"
50	5.61	41.3	35.7	"
60	5.61	41.3	35.7	"
70	5.61	41.3	35.7	"
80	5.61	41.3	35.7	"
Raingun at Hydrant #3 and at a distance of 100 m from the pumping system				

0	4.25	42	40.6	2nd and 3rd Rainguns at #6 &12 hydrants
10	4.99	41.3	40.6	"
20	5.48	41.3	39.9	"
30	5.59	41.3	39.9	"
40	5.60	40.6	39.2	"
50	5.61	40.6	39.2	"
60	5.61	40.6	38.5	"
70	5.61	40.6	38.5	"
80	5.61	40.6	38.5	"
Average		41.2	37.9	
Percent Variation			±6.5	

Table 9. Coefficient of uniformity of Raingun sprinkler as affected by effective diameter of coverage, nozzle sizes and pressure, Bhalwal, Sargodha, Pakistan.

Pressure (m)	Nozzle Size (mm)							
	6 mm		8 mm		10 mm		12 mm	
	Diameter (m)	Cu (%)	Diameter (m)	Cu (%)	Diameter (m)	Cu (%)	Diameter (m)	Cu (%)
14	21	76.25	27	68.94	31	75.44	31	75.24
18	23	70.3	29	70.24	33	76.28	35	85.87
21	25	78.63	29	82.31	33	80.34	37	80.23
25	27	81.83	31	85.17	33	78.74	39	80.08
28	27	86.52	31	86.27	33	88.95	39	78.26
32	27	85.04	31	83.76	33	89.04	39	78.06
35	29	84.22	31	77.99	33	86.68	41	75.41
39	29	81.03	31	71.12	33	90.83	41	78.01
42	31	77.79	33	78.79	35	79.99	41	75.11
46	31	82.40	33	80.56	37	86.19	45	70.88
49	27	85.81	35	81.63	37	85.81	45	75.82
53	27	85.01	35	83.26	37	81.70	45	74.88
56	27	84.94	37	78.11	37	85.15	45	73.77

Table 10. Hydraulics of Raingun sprinklers recommended for local manufacturing and design for farmers in Pakistan.

Type of Raingun	Nozzle Diameter (mm)	Working Pressure (m)	Discharge of Sprinkler (lps)	Radius of Coverage (m)	Application Rate (mm/hr)
PY_{1-20}	6	30	0.66	19.0	2.09
		40	0.76	21.6	1.80
	7	30	0.85	20.8	2.24
		40	0.95	22.9	2.08
	8	30	1.11	22.4	2.54
		40	1.28	22.6	2.86
PY_{1-30}	9	30	1.38	24.2	2.70
		40	1.57	24.6	2.98
	10	30	1.67	25.6	2.94
		40	1.92	26.6	3.11
	11	30	2.03	27.6	3.06
		40	2.35	28.5	3.31
	12	30	2.35	27.2	3.65
		40	2.74	28.5	3.86
PY_{1-40}	12	30	2.64	27.7	3.94
		45	3.17	31.7	3.64
	13	30	2.94	28.6	4.13
		45	3.75	30.8	4.52
	14	35	3.58	31.9	4.03
		45	4.08	32.5	4.43
	15	35	4.36	34.0	4.34
		45	4.86	35.1	4.53
	16	35	4.83	34.9	4.55
		45	5.44	36.2	4.78
PY_{1-50}	16	40	4.97	37.2	4.11
		50	5.58	38.7	4.26
	18	40	6.28	38.9	4.75
		50	7.00	40.0	5.03
	20	40	7.56	41.1	5.10
		50	8.47	42.3	5.42

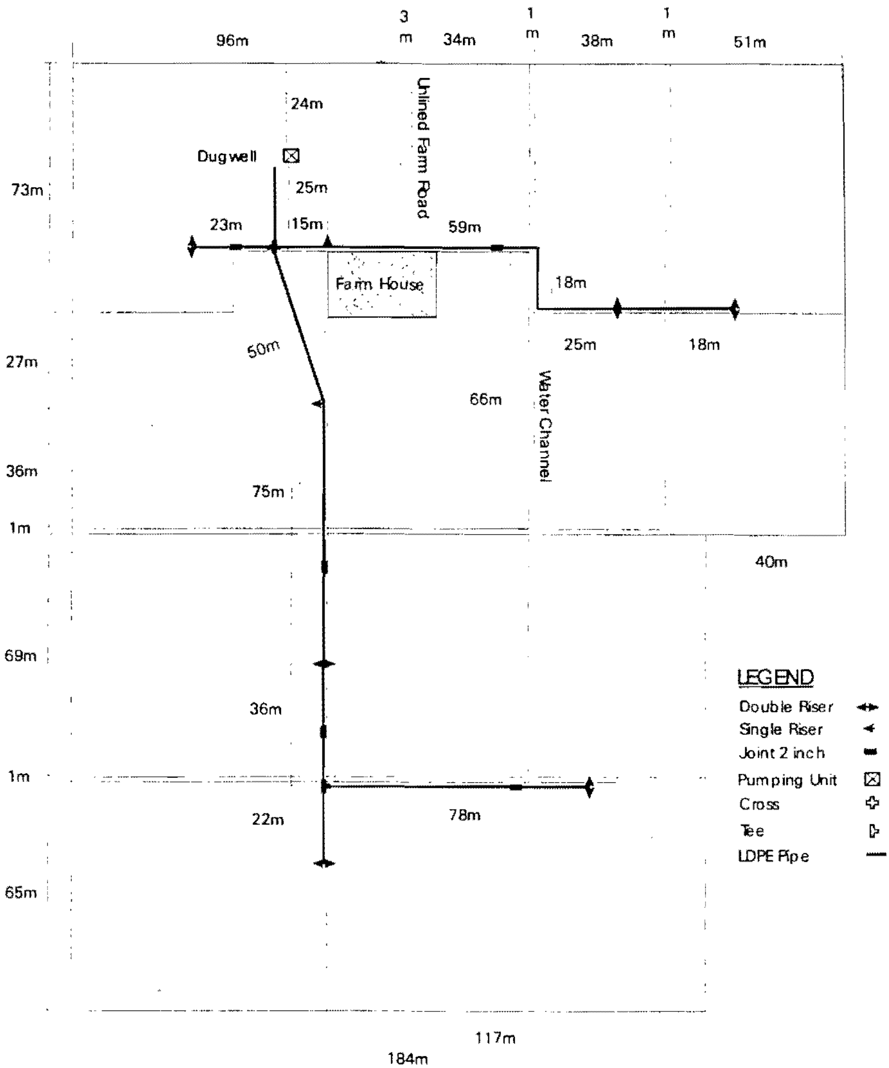

Figure 1: Line Diagram of Raingun Sprinkler Irrigation System Ahmad Bukhsh Farm Chak 6ML Bhalwal

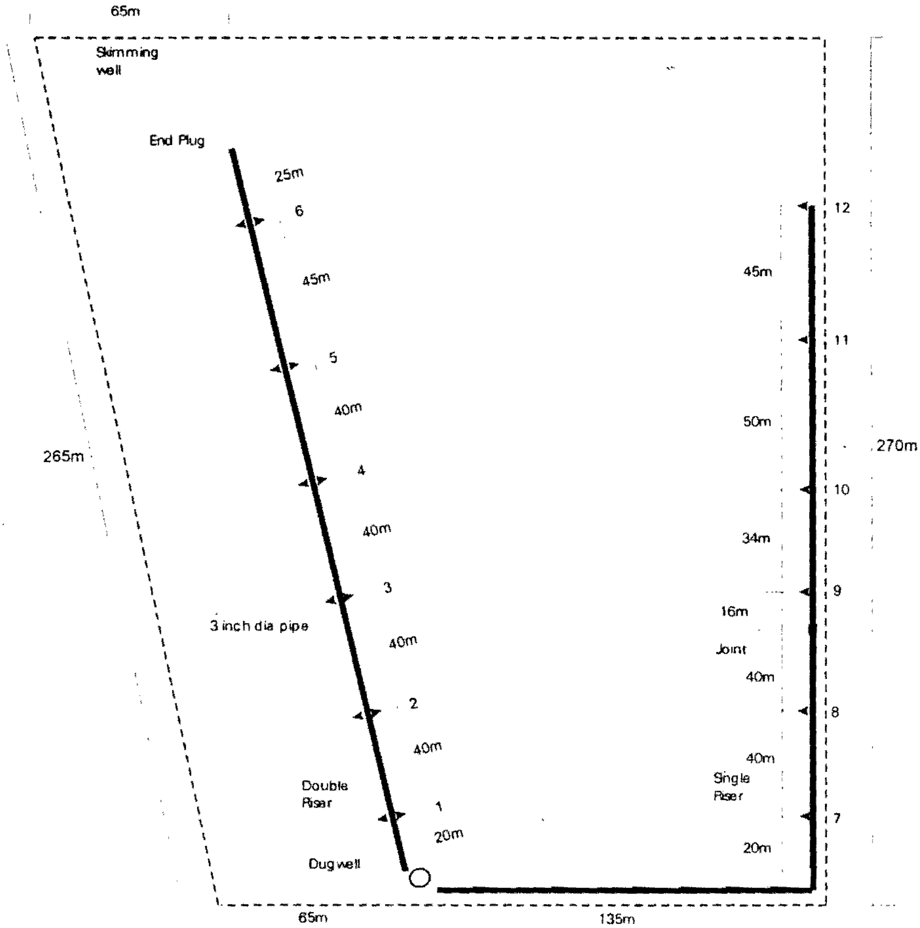

Figure 2: Line Diagram of Raingun Sprinkler Irrigation System Qadir Farm Thathi Noor, Bhalwal

Appendix I. Design of Raingun Sprinkler Irrigation System of Ahmad Bakhsh Farm, Chak # 6 ML, Bhalwal, Sargodha, Pakistan.

PUMP

Engine Power	= 8 hp
Pump Discharge	= 3 lps
Pressure	= 60 m

Design of Manifold #1

Maximum length	= 176 m
Pipe Diameter	= 50 mm
Raingun Discharge	= 2.74 lps at 12 mm nozzle
Frictional Losses	= 7.8 m

Design of Manifold #2

Maximum Length	= 264 m
Pipe Diameter	= 50 mm
Raingun Discharge	= 2.74 lps
Friction Losses	= 11.7 m

Head Loss for Maximum Operational Line

Friction Losses in Manifolds	= 11.7 m
Suction	= 6 m
Friction Losses in Laterals	= 2.5 m
Connections and Valves	= 1 m
	===========
Total Head Loss	**21.2 m**
	===========

Total Head	= 60 m
Working head (Min.)	= 38.8 m
Working head (Max.)	= 48.7
Variation	=4.95m, ±11.5%

Appendix II. Design of Raingun Sprinkler Irrigation System of Qadir Farm, Thatti Noor, Bhalwal, Sargodha, Pakistan.

PUMP

Engine Power	= 18 hp
Pump Discharge	= 8.22 lps
Pressure	= 60 m

Design of Manifold #1

Maximum length	= 250 m
Pipe Diameter	= 75 mm
Raingun Discharge	= 5.5 lps [for 2 rainguns (PY_1-30) with 12 mm nozzles
Friction Losses	= 5.6 m

Design of Manifold #2

a)	Length	= 135 m
	Pipe Diameter	= 75 mm
	Raingun Discharge	= 2.74 lps for 12 mm dia nozzle
	Friction Losses	= 0.8 m
b)	Length	= 229 m
	Pipe Diameter	= 50 mm
	Raingun Discharge	= 2.74 lps for 12 mm dia nozzle
	Friction Losses	= 10.1
	Total Friction Losses in Manifold	= 0.8 + 10.1 = 10.9 m

Head Loss for Maximum Operational Line (Manifold #2)

Suction	= 6 m
Friction Losses in Lateral	= 2.5 m
Connections and Valves	= 1 m
	================
Total System Losses	**18.4 m**
	================
Total Head	= 60 m
Working head (Min.)	= 41.6 m
Working head (Max.)	= 50.1 m
Variation	= ± 9.3% ± 4.25 m

Appendix III. List of Materials Used for Raingun Sprinkler Irrigation System Installed at Chak #6ML, Bhalwal, Sargodha, Pakistan.

	Materials	Quantity	Amount (Rs.)
PUMPING STATION			
a: **Suction Line**			
i.	Foot valve 2½"	1 No	342
ii.	Suction pipe (GI) 2½"	20 ft	1320
iii.	Bend (GI) 2½"	1 No	130
iv.	Nippel (GI) 2½"	1 No	150
v.	Union (GI) 2½"	1 No	230
	Total		**Rs.2172**
	Percentage of Grand Total		**3**
b: **Delivery Line**			
i.	GI Nippel 2"	4 No.	200
ii.	GI Tee Reducer 2"x2"x½	"2 No.	176
iii.	Pressure gauge	1 No.	450
iv.	Union 2"	1 No.	135
v.	Hose Nozzle ½"	1 No.	10
vi.	GI pipe 2"	8 ft.	544
vii.	Nippel ½"	1 No.	10
viii.	Handle valve ½"	1 No.	65
ix.	Elbow 2"	3 No.	195
x.	Hose Nozzle 2"	1 No.	40
	Total		**Rs.1625**
	Percentage of Grand Total		*2*
c: **Foundation**			
i.	Bricks	50 No.	100
ii.	Cement	1 Bag	180
iii.	Sand	4 ft^3	36
iv.	Crush	2 ft^3	20
v.	Engine 8 hp (Chinese)	1 No	
vi.	Multistage pump	1 No.	17000
vii.	Iron Support for Engine & Pump	1 No.	
	Total		**Rs. 17,336**
	Percentage of Grand Total		**24**

MAINLINE NO. 1

i.	LDPE pipe φ 2"	200 m	13,000
ii.	GI pipe 2"	20 ft.	960
iii.	Tee 2"x2"x2"	4 No.	600
iv.	Hose Nozzle 2"	8 No.	320
v.	Nippel 2"	7 No.	350
vi.	Gate Valve 2"	7 No.	1715
vii.	Pipe Joints 2"	2 No.	26
viii.	Elbow 2"	4 No.	260
ix.	Couplers 2"	8 No.	2080
	Total		**Rs. 19,311**
	Percentage of Grand Total		**26**

MAINLINE NO. 2

i.	LDPE pipe φ 2"	300 m	19,500
ii.	Tee 2"x2"x2"	5 No.	750
iii.	Hose Nozzle 2"	8 No.	320
iv.	Nippel 2"	8 No.	400
v.	Gate Valve 2"	7 No.	1715
vi.	Pipe Joints 2"	2 No.	26
vii.	Coupler 2" in mainline No. 1 & 2	8 No.	2080
	Total		**Rs. 24,791**
	Percentage of Grand Total		**34**

OTHER MATERIALS

i.	Cross 2"x2"x2"	1 No.	150
ii.	Clamps 2"	30 No.	450
iii.	Samad Bond	1 kg.	200
iv.	Cloth	3 m	60
v.	Safeda	500 gms	50
vi.	Raingun with nozzle pegs	1 No.	3000
	Total		**Rs. 8,070**
		Percentage of Grand Total	*11*

Total Materials Cost for the System **Rs. 73,305**

Average Materials Cost per ha **Rs. 13831**

Appendix IV. Materials Used for Raingun Sprinkler Irrigation System Installed at Qadir Farm, Thatti Noor, Bhalwal, Sargodha, Pakistan.

	Materials	Quantity	Amount(Rs.)
1. Pumping Station			
a: Suction Line			
I.	Foot valve 2½"	1	342
ii.	Suction pipe (GI) 2½"	6 m	1320
iii.	Bend (GI) 2½"	1 No	130
iv.	Nippel (GI) 2½"	1 No	150
v.	Union (GI) 2½"	1 No	230
	Total		**2172**
	Percentage of Grand Total		**2**
b: Delivery Line			
i.	GI Nipple 2"	8 No.	400
ii.	GI Tee 2"x2"x½"	1 No.	176
iii.	GI Cross 2"x2"x2"x2"	1 No	150
iv.	GI Bush 2" x ½"	1 No.	25
v.	Pressure gauge	1 No.	450
vi.	Gate Valve 2"	2 No.	490
vii.	Union 2"	2 No.	270
viii.	Bends 2"	4 No.	320
ix.	Reducer 3" x 2"	2 No.	450
x.	Hose Nozzle 3"	2 No.	100
xi.	GI sockets 2"	2 No.	100
xii.	GI pipe 2"	14 ft.	672
xiii.	Nipple ½"	1 No.	7
xiv.	Handle valve ½"	1 No.	65
xv.	Pump size 2"x2½"	1 No.	28,500
xvi.	Prime Mover 18 hp Chinese Engine directly coupled with pump on Iron stand.		
	Total		**Rs.32,175**
	Percentage of Grand Total		**28**
2. Mainline No. 1			
i.	LDPE pipe φ 75 mm	240 m	21600
ii.	GI joints φ 75 mm	20 No.	600
iii.	Coupler	6 No.	1560
iv.	Clamps 3"	30 No.	750
v.	GI pipe 2"	15 ft.	720
vi.	Tee 2"x2"x2"	6 No.	900
vii.	Nipple 2"	12 No.	600
viii.	Gate valves 2"	12 No.	2940

ix.	Coupler 2"	12 No.	3120
x.	Reducer 3"x2"	1 No.	225
xi.	GI plug 2"	1 No.	15
xii.	Hose Nozzle 3"	1 No.	50
xiii.	Screws 3/4"	80 No.	60
	Total		**Rs. 33,140**
	Percentage		**29**

3. Mainline No. 2

i.	LDPE pipe φ 3"	126 m	11340
ii.	LDPE pipe φ 2"	250 m	16250
iii.	Reducer 3"x2"	1 No.	225
iv.	Hose Nozzle 3"	1 No.	50
v.	Clamps 3"	2 No.	50
vi.	GI 2" pipe	15 ft.	720
vii.	GI Tee 2"x2"x2"	06 No.	900
viii.	Hose Nozzle 2"	12 No.	480
ix.	GI Nipple 2"	12 No.	600
x.	Gate Valve 2"	06 No.	1470
xi.	Elbow 2"	07 No.	455
xii.	Clamps 2"	20 No.	300
xiii.	Coupler (one end) 2"	6 No.	1560
xiv.	GI joint 2"	1 No.	50
xv.	Screws 3/4"	50 No.	25
	Total		**Rs. 3,445**
	Percentage of Grand Total		**30**

Other Materials

i.	Samad Bond	2 kg.	400
ii.	Safeda	100 gms	50
iii.	Silver Wire	20 m	30
iv.	Raingun wire pegs & nozzles (PY_1-30)	2 No.	6000
v.	Extension Pipe (LDPE 2" 100m		6500
	Total		**Rs.12,980**
	Percentage of Grand Total		**11**

Total Materials Cost for the System	**Rs. 1,14,942**
Average Materials Cost per ha	**Rs. 20,165**