ADAPTATION OF PRESSURIZED IRRIGATION SYSTEMS IN PAKISTAN

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ABSTRACT

The demand of irrigation water is increasing due to increase in population. More area can be brought under irrigation by using pressurized irrigation systems. The sprinkler and trickle irrigation systems represent pressurized irrigation systems. The goal of the sprinkler irrigation system is to apply water to a field uniformly. The factors like soil type, topography, agricultural practices, economic feasibility, etc are considered before selecting a system. There are different types of sprinkler systems such as solid set, move-stop and continuous. The main advantages include; light, frequent and uniform application of irrigation, minimum labour cost, proper irrigation of problem soils, leaching of salts, etc. Sprinkler irrigation system can be used for high value crops in Pakistan. The portable raingun sprinkler systems are used in the country. Trickle irrigation system provides water directly to the plant through a network of pipes. This is labour, water and fertilizer efficient system. The commonly used categories of the trickle irrigation system are drip irrigation, spray irrigation, bubble irrigation and sub-surface irrigation. The main benefits include reduced water requirement, better control on fertilizer placement and timing, efficient irrigation, etc. Most of the components of the trickle irrigation system have been locally produced and the system is being installed on farmers' fields throughout the country.

1. Introduction

1.1. Shortage of Irrigation Water

Pakistan is basically an agricultural country and irrigation is the lifeblood of its agriculture. The demand of irrigation water is increasing day by day due to increase in population. Muhammad, A. (1982) stated that the Pakistan's agricultural sector is presently confronted with a major challenge: how to increase production to the level required to feed a population growing at an annual rate of more than three percent. In general, agricultural production can be increased by either expanding the irrigated cropped area or by raising the crop yields. The national average yields of major crops are at present far below their production potential. Chaudhry and Ali (1989) expressed that overall scarcity of water, non availability of water at the right time and inefficient utilization of available water appear to be the leading factors restricting expansion in irrigated acreage and causing the gap between actual and potential yield levels. Chambers (1987) described that low level of performance of canal irrigation systems in developing countries is a major concern of many governments and aid agencies. Ahmad et al (1987) has reported shortage of water in the Indus basin to the quantum of 0.763 mhm in the crop water requirements. In the future, the only additional water will be from the savings in conveyance and application losses.

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The Indus basin irrigation system is operating at less than 40% efficiency. The annual availability of canal water supplies can meet only less than 40% of the total water requirements (Ministry of Food, Agriculture and Cooperatives, Government of Pakistan, 1984). The inadequacy of canal water supplies is also evidenced by Johnson et al. 1978, Singh 1981 and Bhatti and Kijne 1990. WAPDA (1983) observed that the availability of canal water supplies significantly vary over the year and do not match with the water requirements at various stages of crop development.

About 6.0 mha rainfed area of the country lacks any regular irrigation facilities. The reason for not having irrigation facilities is that traditional gravity flow irrigation system is not possible due to topography, soil type, shortage of water, etc. Rainfed agriculture is solely dependent on the occurrence and distribution of rainfall. The stochastic behaviour of rainfall possesses serious limitations for sustained and profitable crop production. The yields of major crops are 30 to 50% of the national average crop yields mainly because of drought and lack of available soil moisture at the critical crop growth stages. The planting is often delayed due to uncertain and scanty rains. The plant population and crop stand are poor due to inadequate moisture. If dry spells are prolonged, the crop failures are also common. The farmers hesitate to apply fertilizers when they are not sure about rainfall (Kemper et al. 1978). In rainfed areas, water is available through dugwells, mini/small dams, lakes, streams, nullahs, etc. Some farmers are practicing lift irrigation but face difficulty in shaping the land for surface irrigation. The only option left for the rainfed areas is the use of pressurized irrigation.

1.2. Issues of Surface Irrigation

The continuous flow irrigation system, fixed rotation and limited water supply available at the field turnout are the characteristics of the Indus basin irrigation system of Pakistan. The waterlogging, salinity sodicity, low irrigation efficiency, inequitable distribution of water, etc are the main problems of this system.

At present, the irrigation water application practices are based on traditional methods and the delivery and application efficiencies especially at the farm level are quite low. Lowdermilk et al. 1975; Lowdermilk et al. 1978 and Master Planning and Review Division, WAPDA, 1979b indicated an overall irrigation efficiency of the tertiary system as 45% only.

The Indus basin has a flat topography, poor natural drainage and a semi-arid climate with high evaporation rate which has resulted in the twin problem of waterlogging and salinity. The waterlogging creates the situation of oxygen deficiency, salt buildup and poor workability with soil. Being a supply based system, it cannot accommodate changing water demands during the crop season. Inefficient water conveyance and field application has created wastage of available water resources, low crop yields, salinization of land and water.

The problems and limitations of surface irrigation are under irrigation and over irrigation of field crops, uneven distribution within field due to unleveled fields and difference in infiltration opportunity time at near and remote end of the field. The small quantities of water, required to be applied, especially pre-sowing (Rouni) is not possible because the soil is ploughed and pulverized and intake rate is very high.
1.3. Need for Pressurized Irrigation

Sprinkler and trickle irrigation systems represent pressurized irrigation systems. In sprinkler irrigation system water is jetted through the air to spread it from the pipe network across the soil surface. The usual goal of sprinkler irrigation system is uniform watering of an entire field. It is considered suitable for most of the crops. It is adaptable to nearly all irrigable soils. Water can be applied at any selected rate above 3 mm per hour. In trickle irrigation system water is conveyed through pipe system almost directly to each plant and the soil immediately surrounding each plant is wetted. Water is applied to the crop on a low tension and high frequency basis and very high water use efficiency is possible.

Pressurized irrigation systems are designed to provide irrigation in areas where surface irrigation is either not possible or huge investments are required for land forming. In irrigated areas, especially at tail-end reaches and for sodic soils, there is a shortage of canal water supplies. The pressurized irrigation systems can provide light and frequent irrigations. Shallow and frequent irrigation to sodic soils help to avoid ponding and thus emergence of crops is much better.

Dry spells and droughts affect the production and quality of high value fruits. The sprinkler irrigation can help for life saving irrigation with small quantity of water. Cleaning the foliage also helps to improve photosynthetic activity and the productivity can be improved. Foliar application of chemicals is also possible. The application of chemical and organic fertilizers through pressurized irrigation is very efficient. To bring more area under irrigation pressurized irrigation systems are required to be used in the country. The inefficiency of surface irrigation, probably 20 percent or less on sandy rough lands, is well known. Thus attractiveness of controlled irrigation through pressurized irrigation systems is obvious which have the potential to increase efficiency to 85 percent.

To overcome the problems of inefficient water conveyance and field application through surface irrigation and to meet the increasing demands for additional irrigation development, there is an urgent need to control seepage losses. The pressurized irrigation systems can help to improve field water application efficiency. Considering problems of low crop yield and low cropping intensity, there is a need to use pressurized irrigation systems for life saving irrigation and supplemental irrigation.

1.4. Benefits of Pressurized Irrigation Systems

1.4.1. Sprinkler Irrigation System

Sprinkler irrigation systems are recommended and used on practically all types of soils, topographic conditions, and on almost all kinds of crops. Its flexibility and effective water control has permitted a wider range of soils to be irrigated that have surface water application methods, thereby allowing more land to be classed as irrigable. As a direct result, thousands of hectares of land in the United States, which was previously suitable only for dryland farming or as wasteland, is being irrigated today with high yield. This is particularly evident in eastern Colorado, western Nebraska and Kansas. Similar beginning is already made in the Pothwar plateau of Pakistan to provide supplemental irrigation to Barani lands.

On some saline soils, as in the Imperial Valley of California, sprinklers are recommended for better leaching and crop germination. Sprinklers are especially desirable
where soils have a high permeability and/or low water holding capacity. Sprinklers can offer distinct advantages over other irrigation methods in dense soils with low permeability. In areas where labour and water costs are high, sprinklers can be the most economical way to apply water. In many cases, sprinklers have been shown to increase value, such as in the fresh vegetables and fruit market where colour and quality are very important.

Sprinklers often have multiple uses. The same equipment can be used for irrigation, crop cooling, frost control, and the application of pesticides, herbicides and fertilisers. In addition, sprinklers easily irrigate modern farming practices, which require large equipment and large fields for economical farming operations, with no reduction in efficiency. Many areas in the United States, which annually receive more than enough precipitation to satisfy crop requirements, are installing supplemental irrigation systems. This is due to the fact that usually there is no rain at exactly the right time in the required quantity. A timely irrigation at a critical crop growth stage, applying only a few centimetres of water, can offer more than double yield.

1.4.2. Trickle Irrigation System

Under proper system management, little water is lost to deep percolation, consumption by weeds, or soil surface evaporation. Research results reported in the United States indicate that trickle irrigation increased cotton yield by more than 8 percent. While using 24 percent less applied water as compared to surface irrigation. Trickle irrigation was also effective in controlling the return flow volume and in maintaining relatively low salinity levels in the soil adjacent to the emitters.

In addition to reduced irrigation water requirements and minimization of return flows, trickle irrigation has other positive advantages, which are as follows:

- Effective water control possible with trickle irrigation, water can be applied very efficiently. The portion of the soil with active roots needs to be irrigated, and soil evaporation losses can be reduced to a minimum. The low rate of water application reduces deep percolation losses.
- High temporal soil water level can be maintained with trickle systems. This results in a favourable response by most crops in increasing yield and quality.
- Trickle systems are generally permanent and have low labour requirements.
- Fertilizer can be applied through trickle irrigation systems using fertilizer injectors. Effective control of water results in control over fertilizer application. However, the small amount of water lost through deep percolation results in minimum loss of fertilizer through leaching.
- Wetted surface is only a fraction of the total soil surface. Consequently, there is a reduced potential for weed growth.
- Plant canopy is completely dry under trickle systems. It reduces fungus incidence and other pests, which depend upon a moist environment.
- Matric and osmotic potential are additive. The maintenance of a low matric potential is possible with trickle systems. This results in a lower overall potential, and hence a reduced stress under saline conditions. Therefore, some crops can be grown in areas, which would otherwise be unsuitable with conventional systems. The upper limit of suitable water for furrow irrigation is about 0.75 dS/m, while for trickle irrigation, water as salty as 4 dS/m has been used. Water with as little as 3 milli-equivalents/litre of sodium can be detrimental in sprinkler systems due to
leaf burn.

- Experiments on crops like tomatoes, grapes and sugarbeets have resulted in significantly earlier maturation attained with other irrigation systems.
- Soil surface crusting is a significant problem in some soils. This can prevent emergency of plants, even if these have germinated properly. By maintaining constant high moisture contents, soil surface crusting can be eliminated.
- There is no loss at the edge of fields as can occur through wind drift of sprinkler systems or runoff from surface systems.
- Root penetration in some soils is minimal at low water contents, the high average water contents maintained with trickle systems alleviates this problem.
- Theoretically, water can be applied with trickle irrigation systems at rates equal to the plant water use rate.

A wetted profile develops in the root zone beneath each emitter. The shape of the profile is dependent on soil characteristics and is limited by horizontal flow constraints of the soil. The surface area between plant rows is dry, receiving moisture only from rainfall. Trickle irrigation system provides controlled irrigation for optimum yield for variety of crops.

1.5. Potential Areas for Pressurized Irrigation Systems

1.5.1. Areas Outside the Indus Basin

Initial capital cost of standard pressurised irrigation systems (sprinkler, trickle) is considered to be its limitation for large-scale adoption in Pakistan. Therefore, the high cost and economic consideration limit its use to fruit trees and vegetables of high value grown in specific areas. These areas include the following:

- Areas of Balochistan province, where value of water is high and high value crops are grown.
- Green belts around urban centres, where high value vegetables, fruits and fodder are grown.
- Undulated sandy lands in the Thal, Thar and Cholistan deserts, which are having groundwater of reasonable quality.
- Sandy and undulating riverine areas, where recession agriculture is practiced.
- Un-commanded sandy high areas within Indus basin, which require huge investments for surface irrigation.
- Fringe areas or where water is either saline or extremely scarce.
- Northern Areas and Pothwar plateau where high value crops are grown on terraces with very coarse-textured soils.
- Command areas of small dams like Khanpur dam, where citrus and leachi orchards are grown and the value of fruit is exceptionally high.

In-efficiency of surface irrigation, probably 20 percent or less on sandy rough lands is
well known. Thus the attractiveness of highly controlled pressurised irrigation is obvious, which has the potential to increase efficiency to 85 percent or more. Further, the use of trickle irrigation which utilizes pipe to convey water to the crop fields or directly to plants makes the development of the most sandy lands and rough topography practical even with relatively saline water. Thus, existing water supplies can be greatly extended and a totally new class of lands becomes available for irrigation and development by application of pressurised irrigation technology. There is little question as to the technical feasibility of pressurised irrigation systems, which have already been substantiated on extensive installations throughout the world. The question we face in Pakistan is whether such systems or special adaptations are sociologically and economically practicable at present.

Cost of the system depends mainly on the spacing of laterals. The cost of the unit and the net return from the crop should be compared before a decision is made on installing sprinkler or trickle irrigation system. The main item of expenditure is the cost of the lateral lines. For fruit trees, the trickle system is even more economical than sprinkler irrigation, whereas, for closely spaced vegetables sprinkler system is more feasible. The main item of expenditure is the lateral lines; however, the wider the row spacing the lesser the initial cost. Crops like grapes, almond, apples, papayas, guava, citrus, coconut and other fruit trees can be grown well on trickle irrigation system, whereas high value vegetables can be cultivated by using sprinkler irrigation system.

1.5.2. Indus Basin Command Area

Inefficient water conveyance and field application by surface irrigation in the Indus Basin has created problems, which are as follows:

- waste of scarce water resources as the overall irrigation efficiency is as low as 36%;
- waterlogging of agricultural lands, as water table in 35% area of the basin is less than 3 m and thus these lands are regarded as waterlogged;
- waterlogging in the saline groundwater zone has resulted into salinization of land and shallow groundwater;
- secondary salinization and sodification of soils due to the use of marginal to brackish quality groundwater;
- low crop yields; and
- expensive programmes to control problems caused by inefficient water utilization, i.e. Salinity Control and Reclamation Projects.

Because of these problems and due to increasing demands for additional irrigation development, there is an urgent need to control canal seepage losses, improve field water application efficiency, and establish good irrigation practices.

At present, there are development programmes to control water losses from the extensive water delivery system in the Indus Basin. On the other hand, relatively little work is being done to establish efficient irrigation practices. Therefore, efforts are needed to improve
existing surface irrigation and introduce sprinkler system of simple operation adaptable to farmers and crops and to physical conditions of the country. If we include the investments needed for land development and drainage in the Indus Basin, the investments required for the installation of pressurised irrigation systems seem feasible.

1.6. Limitations of Pressurized Irrigation Systems

1.6.1. Sprinkler Irrigation System

Sprinklers, like most physical systems, do have disadvantages. Damage to some crops has been observed when poor quality irrigation water is applied to the foliage by sprinklers. Poor quality water can leave undesirable deposits or colouring on the leaves or fruit of the crop. Sprinklers are also capable of increasing the incidence of certain crop diseases such as fire blight in pears, fungi or foliar bacteria.

A major disadvantage of sprinklers is the relatively high cost, especially for solid-set systems, in comparison to surface irrigation methods. When gravity cannot supply sufficient head to operate the system, sprinklers can require large amount of energy to supply the necessary pressure. The advantages and disadvantages of sprinkler systems must be assessed economically with other irrigation methods. Likewise, individual types of sprinkler systems should be compared to one another.

1.6.2. Trickle Irrigation System

There are number of problems and disadvantages with trickle irrigation systems. The most important one is that the small flows through emitters require small openings that have historically been plagued by clogging. With the smaller emitter orifices, more filtering and biological controls are needed. Great advances have been made to rectify this problem but it will always require the attention of the designer.

Point or strip wetting is not always an advantage even though water savings and weed control are significant benefits. Salinity tends to accumulate a short distance from emitters and can be transported in the root zone in case of heavy rainfall. In addition, root zone tends to be smaller and more densely distributed. This can result in anchorage and aeration problems for some crops. Interestingly, some of the predatory insects' breed in the weeds around a field and some evidence have been reported that trickle irrigation may cause somewhat higher pesticides demand. In windy areas, dry regions between emitters can yield dust problem.

Solid-set structure of trickle irrigation systems along with filtration requirements makes it a high cost technology. Applicable primarily to valuable row crops, orchards, and vineyards.

1.7. Purpose of the Paper

The purpose of the paper is to describe pressurized irrigation systems, their need, benefits and limitations. Pressurized irrigation technology development and Indigenization; local manufacturing, availability of materials in the country, adaptation of the technology, present state and future needs of the pressurized irrigation systems have also been described.
The objectives of the pressurized irrigation systems are a) apply water to meet peak crop water requirement; b) maintain application and uniformity efficiencies at a desired level; c) energy and water efficient to keep initial capital cost and operational cost as low as possible, and d) simple in operation and maintenance so that farmers can use these systems.

2. Technology Development and Indigenization

2.1. Pressurized Irrigation Systems' Selection Consideration

There are a large number of considerations, which must be taken into account in the selection of an irrigation system. These factors vary in importance from location to location and crop to crop. Briefly, these considerations include the compatibility of the system with other agricultural operations, economic factors, topographic limitations, soil properties and agronomic influences. Irrigation system for a field/farm must be compatible with the other existing farm operations such as land preparation, cultivation and harvesting practices. For instance, the use of the more efficient, large machinery requires longer and wider fields.

2.1.1. Economic Consideration

Type of pressurised irrigation system selected is also an economic decision. Some types of sprinkler systems have high per hectare costs and their use is, therefore, limited to high value crops. Other systems have high labour requirements, and some have fairly high operating costs. Trickle irrigation systems are cost-effective for fruit plants and creeper-type vegetables and very costly for field crops.

Also, some systems have limitations with respect to the type of soil or the topography on which they can be used. The expected life of the system, fixed costs, and annual operation costs should also be included in the analysis while selecting an irrigation system.

2.1.2. Topographic Limitations

Restrictions on irrigation system selection due to topography include groundwater levels, the location and relative elevation of the water source, field boundaries, area of each field, the location of roads, electricity and water lines, shape of the field, and field slope. The slope of the land is very important. Some types of pressurised irrigation systems can operate on slopes up to 20 percent or more.

Shape of a field also determines the type of system. For instance, solid-set sprinklers can be adjusted to fit almost any field shape; whereas, a centre-pivot sprinkler must have approximately round-shaped fields. For a side-roll sprinkler, the field should be approximately rectangular in shape. Trickle irrigation technology can be adapted to almost any shape of the field/farm.

2.1.3. Soil Characteristics

Soil type, soil moisture holding capacity, the intake rate, and effective soil depth are the important factors for the type of system selected. For example, sandy soils have a high intake rate and accept high volume sprinklers and trickle irrigation systems, which would be unacceptable on a clay soil.
Moisture-holding capacity will influence the size of the irrigation sets and frequency of irrigation as evidenced by a sandy soil with low moisture-holding capacity, which requires frequent and light applications of water. A centre-pivot or sideroll sprinkler system would perform satisfactorily in this case.

A number of other soil properties are also significant factors in considering the type of irrigation system that will be most advantageous in a particular situation. The interaction of water and soils due to physical, biological, and chemical processes has some influence on the hydraulic characteristics and tilth. Crusting and erodibility should be considered in each irrigation system design, and the spatial distribution of soil properties may be an important limitation on some methods of applying irrigation water.

2.1.4. Water Supply

Quality, quantity, and temporal distribution characteristics of the source of irrigation water have a significant bearing on the irrigation practices. Crop water requirements are essentially continuous during the growing season although varied in magnitude. A small, readily available water supply is best utilised in a small capacity irrigation system, which incorporates frequent applications. The depths applied per irrigation are, therefore, small in comparison to system having a large discharge available less frequently.

Quality of the water in conjunction with the frequency of irrigation must be evaluated. Salinity is generally the most significant problem. A highly saline water supply must be applied more frequently and in large amount than a good quality water.

2.1.5. Crop Factors

Some of the factors associated with the crops being grown which influence the choice of irrigation system and its eventual management is summarised as under:

- Ŷ tolerance of the crop during both development and maturation to soil salinity and aeration;
- Ŷ magnitude and temporal distribution of water needs for maximum production; and
- Ŷ economic value of the crop.

2.2. Sprinkler Irrigation Technology

2.2.1. Selection of Sprinkler Irrigation System

With careful consideration of the factors outlined above and others as the particular circumstance dictates, the right type of irrigation system can be selected. The array of available sprinkler systems makes this method of irrigation compatible in nearly any situation. For fields planted to trees, vines, or other perennial crops of similar nature, permanently located systems can operate effectively. Crops like berseem, sugarcane, or grains are best irrigated by a system whose parts can be moved away from the necessary cultural operations.

Sprinkler irrigation systems are high initial investment and energy intensive. On the other hand, they are labour, water and fertiliser efficient. No expenditure is required for land levelling, but usually have maintenance requirements that can be more expensive than for surface irrigation systems. A major economic factor is the utility of the sprinkler systems in
providing a cost-effective means of fertiliser and pesticide applications, and the control of plant environments through frost control and cooling.

Cost of sprinkler irrigation systems is minimised when operated continuously during the critical demand period. Thus, these systems tend to favour conditions where the water supply is readily available. Applications tend to be smaller than with surface methods, which not only minimise system capacity, but also reduces the consequences of shallow or badly stratified soils.

2.2.2. Local Manufacturing

Water Resources Research Institute (WRRI) of the National Agricultural Research Centre (NARC), Islamabad realized that the sprinkler irrigation systems must be produced with local skills, technology and materials if continuity and successful implementation has to be obtained. The conventional sprinkler irrigation systems are expensive so manufacturing of solid-set, hand move and raingun sprinkler irrigation system's components was initiated. The WRRI-NARC in collaboration with MECO Pvt. Ltd., Lahore developed a complete range of raingun sprinkler irrigation systems including diesel and electric operated pumping systems, couplers and other fittings and joints. The high pressure low density polyethylene pipes with black carbon and UV stabilizers were produced in collaboration with Griffon Industrial Corporation, Lahore. The Plastic Technology Centre, Karachi provided support in materials testing. These pipes can be used for pressures upto 120 psi.

2.2.3. Availability of System Components

The Chinese raingun models Py1-30 and Py1-50 have been indigenized in the country and are available with MECO Pvt. Limited, Lahore and M. Azam Khan and Co., Rawalpindi. The couplers, joints and other fittings are also available with them. The diesel and electric operated systems can be obtained from them. To keep the systems portable, the pumping unit alongwith power unit (diesel engine or electric motor) is fixed on a trolley with two tyres, two stands and toeing hock. The pumping unit is fitted on a frame which can be fixed if portable system is not required.

2.2.4. Adaptation of Sprinkler Irrigation in Pakistan

The raingun sprinkler irrigation systems have been installed throughout the country for demonstration and introduction of the technology. In Barani areas, these systems are being used for supplemental irrigation and life saving irrigation to fruits, vegetable and field crops. The pre-sowing irrigation (Rouni) is also being applied with this system to sow the crop at right time. The fodders, wheat crop, sunflower, groundnut, chickpeas have been irrigated with raingun sprinkler irrigation system. In the Khanpur dam area, the raingun sprinkler irrigation system is being used for establishment of young orchard, efficient irrigation to orchard and vegetables, washing of leachy and citrus, fertigation of fruit trees, cooling and frost control in orchards. Raingun sprinkler irrigation systems have been used in Muzaffargarh, Bahawalpur and Hasilpur areas for stabilization of sand dunes and irrigation to field crops and fruits. In the irrigated areas, it is being used to irrigate the un-commanded areas within canal commands for supplemental irrigation and salinity control.

2.3. Trickle Irrigation Technology
2.3.1. Selection of Trickle Irrigation System

With careful consideration of the factors outlined above and others as the particulars circumstance dictates, a right type of irrigation system can be selected. The array of available trickle irrigation system makes this method of irrigation compatible in almost any situation. For fields planted with trees, vines or other perennial crops of similar nature, permanently located systems can operate effectively. Vegetables are best irrigated by a system whose parts can be moved away from the necessary cultural operations. Standard trickle irrigation systems are not easily moved are, therefore, most compatible with trees and vines. It should be noted, however, that trickle irrigation systems are widely used in row crops.

Trickle irrigation systems are high initial investment and energy intensive. But, at the same time, these are labour, water and fertilizer efficient. No investment is involved in land levelling, but usually there are maintenance requirements that can be more expensive than surface irrigation systems. A major economic factor is the utility of the trickle systems in providing a cost-effective means of fertilizer and pesticide applications.

Cost of trickle irrigation system is minimized when operated continuously during the critical demand period. Thus, these systems tend to favour conditions where available. Applications tend to be smaller than surface methods, which not only minimize system capacity, but also reduces the consequence of shallow or badly stratified soils.

2.3.2. Local Manufacturing

In trickle irrigation system, the main cost is the cost of pipes to be used to convey water from pumping unit to the individual plant. Therefore, efforts were made to produce pipes for laterals in the country. The low density black polyethylene pipes with UV stabilizers and carbon contents have been locally produced using locally available materials and technology. The Plastic Technology Centre, Karachi provided technical support in analyzing the material, finding constituents of the pipes and testing the material.

The next important component of the trickle irrigation system is the emitters. The pressure compensating turbo emitters, variable flow spiral emitters and LDPE micro-tubing of 1 mm diameter have been locally produced. The fittings and accessories like pushfit connections for 13 mm diameter lateral pipe, pushfit reducer adapter for 13 mm diameter lateral, quick coupler for 25 and 50 mm diameter pipes, filter, etc have also been developed locally. The other fittings like gate valves, elbows, tees, etc can easily be obtained from the local market.

2.3.3. Availability of Systems' Components

All the components of the trickle irrigation system have been locally manufactured using locally available materials and technology in collaboration with local industry. The technical support was provided by WRRI-NARC, Islamabad. The trickle irrigation systems' components are now available from Griffon Industrial Corporation, Lahore, New Tech (Pvt) Ltd., Islamabad. In fact many other industries are now producing LDPE pipes which can be used for trickle irrigation systems.

2.3.4. Adaptation of Trickle Irrigation in Pakistan

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Trickle irrigation systems are basically used for irrigating high value fruit trees and orchards. Efforts have been initiated to introduce micro sprinklers to fulfill the needs of the farmers interested in intercropping during initial 4-5 years which plants are young. Some of the farmers have approached WRRI for designing of trickle irrigation system for vegetables, especially potato.

The trickle irrigation systems have been installed in the areas where water is of high value, like, Balochistan, Northern areas, D.G. Khan, Kohat, Bahawalpur, Nowshera, Haripur and Attock. These systems have been installed for fruit trees of guava, loquat, lemon, citrus, leachi and apple.

During the drought periods, a group of farmers from Sargodha district approached WRRI-NARC and demanded trickle irrigation system for their farms. A three acre demonstration plot has been establish for orchard at Bhalwal, Sargodha.

3. Present State of Adaptation in Pakistan

3.1. Sprinkler Irrigation

Sprinkler irrigation is being introduced in the country. It has been installed in several demonstration plots in the country. Furthermore, progressive farmers are importing sophisticated systems such as centre pivots and linear move sprinkler machines.

Conventional sprinkler irrigation systems are capital intensive. Therefore, some modifications were needed to suit the socio-economic conditions and physical requirements in Pakistan. 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.

Sprinkler irrigation system can easily be introduced for high value vegetables and fruits in areas where either value of water is high or soils are of light texture. Later on, the system can be extended to field crops if the economic conditions permit its installation. The recommended systems for various physical, social and economic conditions are presented in Table 1.

### Table 1. Recommended Raingun sprinkler irrigation systems for various physical and socio-economic conditions in Pakistan.

<table>
<thead>
<tr>
<th>Farm Size (acres)</th>
<th>Raingun Model</th>
<th>Working Head (m)</th>
<th>Type of Prime Mover</th>
<th>Area of Coverage Per Setting (acres)</th>
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<tr>
<td>4</td>
<td>PY1-20</td>
<td>30-40</td>
<td>Electric/Diesel</td>
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</tr>
<tr>
<td>60</td>
<td>PY1-80</td>
<td>60-70</td>
<td>PTO driven</td>
<td>2.50</td>
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<tr>
<td>100</td>
<td>PY1-80</td>
<td>70-80</td>
<td>PTO driven</td>
<td>3.80</td>
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Most of the system components of solid-set, hand move and Raingun sprinklers have been successfully manufactured in Pakistan, except the cost effective aluminum pipes would need to be imported or adaptations are needed to suit Pakistani conditions. WRRI-NARC, Islamabad in collaboration with MECO Pvt. Ltd. Lahore developed a complete range of Raingun sprinkler 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 Pipe Industries, Pvt. Ltd., Lahore. These are available in 13, 25, 31.25, 37.5, 50, 62.5, 75 and 100 mm diameter, which can be used for pressures up to 120 psi. In the near future, other low-pressure systems will be developed. The estimated average installed cost of Raingun sprinkler irrigation systems in Pakistan is in the range of Rs. 12,000-15,000 per acre for a system of at least 5 acres using electric/diesel operated pumping systems. The cost of portable Raingun sprinkler irrigation systems will be much less but difficult to operate due to movement of pipelines. However, portable systems will be more economical, where water availability supports the use of portable systems.

In general, the mainline and manifolds of Raingun sprinkler irrigation systems are buried in the ground and hydrants are installed to provide water through flexible laterals for sprinkler irrigation. These systems are adopted by farmers, especially those who are interested for inter-culture between rows of fruit plants. In the Barani areas, where the field conditions permit, the use of portable Raingun sprinkler systems is more feasible for supplemental irrigation to wheat and chickpea. In areas of chickpea cultivation, one irrigation at planting or critical stages of crop development can double the yield. Thus economics of sprinkler irrigation is very attractive.

### 3.2. Trickle Irrigation

The conventional trickle irrigation system provides optimum soil water conditions when properly designed, installed and managed, and requires a minimum of labour. However, at the beginning, the emitters would have to be imported. But, sooner, these would be manufactured in Pakistan.

In essence, this form of irrigation involves the use of portable hoses to supply water directly to small basins around each tree or near to each plant. The hoses would be systematically moved within the orchard to complete an irrigation every four days on sandy soils. The system could be redesigned for a longer irrigation interval where soil conditions permit.

In these systems, the water will leave the tubewell, pass through a simple strainer, a fertilizer injection device, flow meters and through pipelines that feed the hoses. The water will only make exit from the system at and into the basins provided at each tree and there will be no chance for losses except through poor distribution or over-irrigation of the basins. If the labourers systematically move the hoses, the efficiency of the system will be in the neighbourhood of 90 percent.
The modified hose-fed concept is particularly adaptable in Pakistan since it makes a reasonable compromise between labour and resource inputs. These systems should provide optimum water management on all types of soils for a variety of vegetables and fruit orchards. Furthermore, most of the components of these systems can be manufactured from locally available resources by existing industries. The systems need to be designed in a simplified way so that it can be understood and operated by the farming community.

These adaptations are also suitable for matured orchards, which were initially developed on flood irrigation and farmers want to convert due to shortage of water. Trickle irrigation design for matured orchards, which were raised on flood irrigation, is not only complex due to extended root system but also costly. Therefore, such adaptations are essential for matured orchards to develop feasible and cost-effective systems.

LDPE pipes developed for pressurised irrigation systems are not sufficiently flexible to use as a hose, which can be moved by labour to reduce the capital cost. Therefore, PVC flexible hose can be used as laterals, which can be moved manually.

Modified hose-fed irrigation systems are costly compared to flood irrigation in terms of capital cost, but they are economical in terms of operational cost due to increase in electricity tariff and diesel prices. Furthermore, large discharges are required for flood irrigation. For pipe-flow irrigation systems, water is applied directly to plants, which requires much less amount of water. At least the water required is reduced to one-third to one-fourth. This is a substantial saving in terms of electricity or diesel. Furthermore, the size of the prime mover can be reduced tremendously. For example, the system installed at the Ayub Farms in Khanpur on 20 acres of orchards requires only 3 hp on single-phase system. Thus residential electricity connections can be used for small to medium size farms, if sufficient power supply is available.

4. Future Requirements

4.1. Energy and Water Efficient System

The main purpose in the design of an irrigation system is to maximize net benefits and minimize cost. This is because of the low investment capacity of the small farmers. The cost of energy (diesel and electricity) is increasing day by day. This has made tubewell irrigation and pressurized irrigation very expensive. This situation demands energy and water efficient irrigation systems. The WRRI-NARC is working on energy efficient and water efficient pumping systems to be developed locally. The initial results of ceramic balls indicated a decrease of about 30% in fuel consumption of diesel engines. A magnetic modifier indicated a decrease of 20% in fuel consumption of diesel engines. Dhani Buksh et al (2000) indicated that EMz Ceramics for 3 and 8 hp engine pumpset provided decrease in fuel consumption of around 25-34%. The testing of this technique has been initiated in irrigated areas of Punjab and Balochistan in collaboration with On-Farm Water Management Directorates.

4.2. Design Support

Designing of an irrigation system is basically an art in which efforts are made to maximize efficiency and minimize labour and capital requirements. The WRRI-NARC has developed handbooks in which procedures for designing pressurized irrigation systems have
been described in detail. But each farm will have its own design due to difference in soil type, water source, quality of water, capability and capacity of individual farmer, choice of farmer, labour availability, automation required, etc.

There is a need to train engineers in the design of pressurized irrigation systems so that they can provide service to the interested farmers according to their needs and requirements. In the design process, different alternate options are considered to select the best satisfying design. Some times trade-off has to be made from the standard design procedures. Some of the examples of trade-off are as under:

Uniformity of irrigation application influences the system design. For achieving high uniformity in trickle irrigation, each emitter discharge must have minimum variation from the average. This implies that pressure throughout the system must be uniform. Since friction losses in pipe network are unavoidable, the desire to ensure nearly uniform pressure distribution requires that pipe diameters be relatively large and individual pipe lengths be shortened. Thus higher uniformity requires higher costs, which normally will be more than the benefits because of increased yields. In practice, the uniformity in trickle irrigation system design is maintained arbitrarily limiting pressure variation to within 10% of the average design value, thereby eliminating the uniformity-yield considerations.

Higher uniformity in sprinkler irrigation is achieved through minimising discharge variations and by overlapping in the range of 25-50%. Thus there is a flexibility in sprinkler irrigation to achieve higher uniformity by overlapping of wetting circles because uniformity is a function of not only the effective radius but also the wind speed and direction.

There is also a competition between the costs of pumping and the cost of pipe. If the pipe diameters are reduced the head loss in subunits will increase and must be compensated with higher energy. Similarly increasing pipe diameters can reduce the pumping energy. The optimum level will be achieved by minimizing the sum of both pipe and energy costs. The other tradeoffs include labour versus automation. This is again related with the system cost and the farmers’ preferences. The systematic procedure for optimization requires a mathematical expression of relationship between the optimizing criterion (minimum costs) and the decision variables (pipe lengths and energy costs). Considering socio-economic situation of the farming community in Pakistan, both the decision variables are important. However, in practice, there are flat electricity rates based on horsepower of the electric motor. Therefore, minimizing energy cost will be an important objective function because electricity is not easily available and farmers now prefer diesel-operated pumping systems.

Further rise in diesel prices and extremely low-efficiency of the prime movers have forced farmers to re-consider electric motors instead of diesel engines with a condition that the size of the prime movers has to be reduced. This reduction is aimed to minimise the energy cost. Some of the farmers have forced the design engineers to even design low-pressure energy efficient systems using single phase electric motors, because they are facing difficulties to obtain and maintain three-phase connection of electricity. Furthermore, optimization of design must be given due emphasis considering the operating cost of the system in terms of unit irrigation cost. This will also require clear understanding of the design objectives by the engineers involved in this process.

4.3. Services to Farmers
The pressurized irrigation systems require higher management skills as compared to surface irrigation systems. There is a need to involve farmers in all the processes starting from survey, design, materials selection, installation, operation and maintenance of the system. The active involvement of the farmer and participation is must for the success of the system. The involvement of the farmers' labour who ultimately will be operating the system, is an important element in the successful operation of the system.

There is an urgent need to establish private irrigation companies involving jobless engineers and giving on-job training in the design of irrigation systems. The irrigation companies should not only help in designing and installation of the system but also provide practical training in operation and maintenance of the system and application of irrigation water for different crops and at different crop growth stages.

Initially some financial support in the shape of interest free loans is required for the irrigation companies. The WRRI-NARC has started providing on-job training to the jobless Agricultural Engineers in the surveying, designing, installation, operation and maintenance of pressurized irrigation systems. The Government of Pakistan is considering for providing financial support to the irrigation companies. The experience of establishing private irrigation companies is running successfully in many other countries.

4.4. Manufacturing Requirement

The WRRI-NARC has developed handbooks of pressurized irrigation systems in which specifications for manufacturers have also been described for sprinkler and trickle irrigation systems.

The local manufacturing of alluminium pipes is very essential for sprinkler irrigation system. Even in the United States, the local manufacturing of alluminium pipes gave a boost to the sprinkler irrigation industry in the country. The second important item to be manufactured in the country is the high pressure pumps especially for deepwell pumping. The groundwater level in the areas outside Indus basin is deep and centrifugal pumps do not operate satisfactorily in these areas. Some of the imported pumps are available in the country for deep-well pumping but they are quite expensive and out of reach of common farmer.

The joints and fittings, especially, for trickle irrigation system have to be developed in the country. Presently the G.I fittings are being used as the polyethylene pipe fittings are not available. The joints and fittings would be cheap if developed locally using polyethylene pipe. The manufacturing of pressure compensating turbo emitters is also required. The financial support is required for manufacturing of quality turbo emitters. Presently, micro-tubing is used as emitters in the trickle irrigation systems.

5. References


