Micro Irrigation Engineering

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Lecture – 24
Drip Irrigation: Design Considerations and System Layout

Hello participants, I welcome you to lecture 24. Lecture 24 is on drip irrigation design consideration and system layout. In lecture 23, we discussed about drip irrigation system. We learned about the different components of a drip irrigation system. Now, having learned about the different components of drip irrigation system, we are interested to use this system, install the system in the field, we should have prior information. We should design the system. It should be hydraulically efficient. It should be economical and then find out the suitable layout as per the field requirement.

So, in this lecture, we are going to cover the points needed for the planning of a drip irrigation system. After knowing the information available, having the resource inventory done, then we will take up what are the general points which are needed for designing a drip irrigation system, wetting pattern, percent wetted area by the particular type of drip emitter or set up, group of drip emitters, how to determine crop water requirement, and finalizing the layout of drip system.

When we talk of drip irrigation system design, our aim is to achieve higher irrigation efficiency means, we are interested to get high emission uniformity from the drip emitters. And this is only possible when our system is perfectly hydraulically designed and the drippers are properly chosen. They are free from any problems related to clogging, then only we can achieve high emission uniformity.

Our aim is to maintain optimum soil moisture levels for optimal crop yield. So, it should not over irrigate; it should not under irrigate. So, the moisture content is a very important parameter which will help in the plant growth, and ultimately, it will result in getting the high crop yield. To keep both initial investment and annual cost at a minimum level. This is a very important thing when we are deciding particular design and layout.

So, we have to see that the investment, there should be minimum attachment within the system and also, see that annual cost which is matter. So, if it is properly designed, we will be getting the annual cost reduced. So, we should aim for this point also. The other point is to design a suitable type of system, which will last long and also, for the longer time period, life period of the system, it should perform at high efficiency. It should perform well.

The other point is to design a manageable system which can be easily operated and maintained. Yes, designs should be user-friendly, anybody who wants to use it, then they can be properly operated and easily maintained. This is for any designs; not only for drip system but this would be easily operated and maintained, then only it is an efficient design.

To satisfy and fulfill the need of crops, yes, the design should meet the crop water requirement; it should meet the fertigation requirement means it should have the adequate capacity of the pump, the adequate capacity of the fertigation unit, adequate capacity of the all other systems, which have been used as the components and then also finally, it helps to fulfill the requirement of the user, crop grower or farmers.

Now, what are the different steps one should follow when we are taking for the design of a micro irrigation system? So, the first most thing is that one should make the inventory of resources. What are the resources? This means, what is the type of soil, what is the land elevation, what is the source of water, whether the source of water is adequate, what is the quality of water, etc. So, these are some points that come under the resource inventory and then we should collect those data, analyze them carefully that will become an input when we are taking design.

Computation of peak water requirement. Computation of peak water requirement, if we are able to get the water requirement of the crop during peak season, peak demand, or during summer month when we are considering means our system design is a conservative design which will take care of all season.

When a crop is at the initial stage, when it is in the maturity stage, when it is at the late season's stage so, peak design will take care of that. Deciding the appropriate layout of the system, this is in the topic, we will discuss about what would be the appropriate layout one should follow. Then choosing drip emitters. So, having got the type of soil, having got the particular type of crop, then we will choose an appropriate emitter and its capacity.

Hydraulic design of the system in terms of lateral means to design for lateral, design for sub-main, design for main pipeline and then finally, we will estimate what is the total pressure requirement, what will be the total water requirement, then we will get the horsepower requirement of the pump.

Now, going little detail about the inventory of the resources and data collection means we need to have the scale plan of site means map of the place that is the location map where the irrigation area is to be irrigated. So, what is the area it is there? And then what is the topography elevation? What is the highest elevation in the field? Because that will be needed while we are finding out the head requirement.

Irrigation water source, is it a surface water or groundwater? Then whether the quantity of water which is available, is it adequate to meet the requirement? Because this we will be considering for that period when crop is in the peak growth stage means peak requirements. So, whether that much water will be available. So, one is that peak water requirement on daily basis, then total water requirement for the whole season and then what is the quality of water.

How much is the sand, silt, and clay? And then the other you know the anion, cation, which they are in the water, can it be separated? That should be analyzed before we are thinking of a drip irrigation system. Soil type means what is the texture. What type of soil it is there? Accordingly, we will choose a particular type of emitter.

Local climatic data, weather data, it is important. So, weather data analysis will be done. We discussed about crop evapotranspiration in the basic fundamental part of this course, regarding estimation of evapotranspiration requirement of the crop, reference evapotranspiration, this already I have discussed. So, that will be needed using the data and in the previous slide, I was telling the peak water requirement ET_0, daily it is needed for operating the system, but ET_0 particularly during peak season or during summer month maybe for some crop will be needed.

Then the proposed planting, what type of crop or a plant? And then what is the spacing between the crops? What is the type of crop? And then what is the initial or your maturity stage of the crop? So, all these are to be needed.

Then, I told you about the quality of water. So, quality of water, we will need that what is the type of filter we will be needing. Whether 2 filters are adequate, one filter itself is adequate, or for all 3, 4 types of filter will be needed that will be decided based on the quality of water available. And we said then, if I am taking a filter, it should give a high filtration efficiency. It should not get clogged. There should be a minimum head loss due to filter elements. So, we will take care of the chemical quality of water, what is the secondary safety about the screening, then the other part is your pressure variation, pressure due to the filter, pressure variation due to elevation in the field.

What is the operating pressure which is needed for the particular emission device that is to be used that can be operated, degree of control of pressure? This is another component that should be taken care and then one should know the discharge pressure relationship means when we are considering what is the discharge needed, how much pressure it needed. So, accordingly, a hydrant will be placed, your line should be connected with them with a source of water. So, that it is delivering an appropriate discharge and then we should have a provision to monitor the flow rate. We should have provision to monitor the pressure at different points.

The other point which I was telling you in previous class about the wetting by a dripper. It forms an onion shape or it forms the elliptical shape. So, that is the wetting pattern. What type of wetting forms when the water is being supplied by a dripper? So, it means the water will wet in a horizontal or a vertical direction.

So, you can see here, when water is being given by one point source drip emitter, the horizontal spread of water is more as compared to the vertical spread of water. This happens when water is being given with the dripper in clay soil. In loamy soil, the shape you know, the volume of water is the same, which has been given, but it has taken a different shape. When you come to the sandy soil, the vertical moment of water is more as compared to the horizontal movement. So, this kind of situation happens when we are considering a particular type of dripper. So, we will work out the wetting pattern. Wetting pattern, we will estimate in terms of percent weighted area. Now, the percentage weighted area compared to the entire cropped area depends on the volume, rate of discharge at each emission point, the spacing of emission point, and the type of soil.

I would say that it is the soil, it is the particular type of dripper, and the time of application of water that will be important while the horizontal as well as vertical movement of water from the point source emitter when the water moment, it takes place. So, Pw is determined from an estimate of average area, weighted at a depth of 15 to 30 centimeter beneath the emitter that is divided by the total cropped area served.

So, we can see here system having high Pw provides more storage of water means that will be the thing that that how much is the Pw percentage wetting area provides more storage of water. So far, wider spacing crops, Pw should be between, a practical value I am telling you, 30% to 70%. Now, 30% what I am telling, this is when the horticulture crop when it is in the initial growth stage and it goes to 70% when it is in the fully grown stage.

So, when we are designing the system, one should take about 60 to 70%. In that range, this should be taken, it is given below 67% to keep strips between rows dry for cultural practice. Now, low Pw reduces the loss of water. It is correct, if lesser will be the wetting means, the loss will be low, evaporation will be low, and means where the cover crops are used.

Now, it is costly to have a low Pw for more emitters, and tubings are required. When we need to have more Pw when we want to so, then what will happen? We will be using drippers, these are your tubings wherein the inline type of dripper are used, so that one complete strip can be made. So, closely spaced crop with the rows and emitter lateral less than 1.8 meter, the percentage weighted area approaches to 100; means when the closely spaced crop, we are considering a vegetable crop, their wetting is maintained at 100%. And on sloping land, the wetting pattern may be distorted due to the effect of the slope.

Now, we want to find out how to get the value of Pw that is the percent wetting area. So, this can be estimated by,

$$P_w = \frac{N_p S_e w}{S_p S_r} \times 100$$

Where, Np is the number of emitters per tree, Se the spacing of emitters in the lateral, w wetting width, Sp is the plant spacing, and Sr is the spacing between the rows. So, this way, one can find out for the single lateral system.

Now, when we are finding out particularly for micro sprinkler or spray types of emitter, then one can find out the percentage wetting.

$$P_w = \frac{N_p\left[A_p + (S_e \times PS)/2\right]}{S_p S_r} \times 100$$

Where Ap is the soil surface area directly wetted by sprayers, Ps is the perimeter of the area directly weighted by sprayers. So, this will give for when we are considering the spray system or micro sprinkler system wetting area, one can calculate.

This is a study which has been reported by James in 1998, that the maximum diameter of a weighted circle that is formed by a single emitter device when it is discharging about 4 litre per hour for various soils. You can see here if it is a coarse soil, it is a homogeneous coarse soil, the water movement is 45 centimeter; in case of varying layers, it is wetting bulb is 75 centimeter diameter and when it is a varying layer, generally having medium density 110 centimeter.

So, as we go for the varying layers means it is a layered kind of system it did exist. When there is medium density soil it exists, what we find is that the wetting bulb or wetting diameter Aw, it is more as compared to the other areas. So, this is the way it is estimated. And you can see how a typical, means, there are 2 laterals which are spaced and then how the particular drip emitter is discharging.

So, here, what you are seeing, this is the spacing between the drip lateral. So, we need to see that there is a proper overlap of this wetting bulb which has been formed by the drip emitter. So, that the effective root zone depth of the plant is irrigated.

Now, computing the irrigation water requirement. As we have learned in the previous same concept that is used here also. Irrigation water requirement is the amount of water in addition to the rainfall that must be applied to meet the crop water evapotranspiration without reduction in the yield. So, crop water requirement under drip irrigation system, it will vary with the different crops. Under surface and sprinkler irrigation, primarily the land area-weighted is reduced resulting in less evaporation from the soil surface.

So, the peak water requirement, we can give here

$$Q = ET_o \times K_c \times S_p \times S_r \times W_a$$

Where ET_0 is the reference evapotranspiration in millimeter per day, Kc is the crop coefficient, the area under each plant that is the spacing between the plant, Sp, and the spacing between the rows, Sr of these plants, wa is percent weighted area. The same thing, it is a Pw. It is Pw. It is the area of each individual plant and this is the ETc. This, already we have studied the ETc. ETo into Kc is actual crop evapotranspiration.

So, this way now, ET0 is, though it is written here, it is reference evapotranspiration, but we need to get ET0 value for peak requirement when there is a high demand of atmosphere, it is there that will cause the more ET0 values that mean temperature, solar radiation, wind, they are active then only ET0, means it is that particular crop, there is no shortage of moisture and then it is at the full growth stage.

Now, when we want to find out the capacity of drip irrigation system, so, it is necessary to determine the system capacity, operating time per season to design a pumping plant, and pipeline network that are economical and efficient. According to Keller and Bliesner in 1990, they have given this expression to estimate the capacity of drip irrigation system. The capacity of the drip irrigation system, which is nothing but the total quantity of water or discharge to be supplied by the pump. So, it is given by

$$Q_s = K \frac{A \times q}{N_s \times S_e \times S_l}$$

Where A is the area of the field, q is the discharge of a particular emitter, Ns is the number of operating hours, the row to row spacing that is the spacing between the plant/emitter, Se, and then Sl is the spacing between the lateral. So, we will get the value of the particular area, how much area is to irrigate the plant means the particular area between each individual plant and then total area and the discharge is known, divided by the operating hours. Then one can know that what will be the discharge. So, this will give the total system capacity.

Now, here time of operation is another component. Time of operation means how many hours the system should be operated. So, having got, if we know the volume of water supply needed (V), that volume, we will get based on the what number of plants and its ET0 value means area multiplied by the ET0 multiplied by the number of plants that will give this thing and then that is divided by the q.

$$T = \frac{V}{N_e \times N_p \times q}$$

So, this will give us the total time of operation of the drip system.

Now, the capacity of the drip system can be verified means, can be estimated by using that flow carried by the lateral, the discharge of one emitter multiplied by the number of drippers or emitters in each lateral. Flow carried by the sub-main pipeline is the number of lateral in each submission pipeline multiplied by a discharge of one lateral. So, this is a Q_L multiplied by the number of lateral. Similarly, the discharge carried by the main pipeline is the discharge of one sub-main manifold multiplied by the number of the sub-main pipeline.

Now, each drip irrigation system should be, can be laid in different ways depending on the source of water supply, depending on the field layout. So, it is possible to apply water to the whole field by drip system method at the same time. As far as possible, of course, it will if the area is very large, one can divide the area into a number of zones, but for a smaller area, one can give water at all the points.

So, this is the way that when it is given, water is being brought from the source of supply, main is laid just to parallel to the width and then directly on the main lateral pipeline has been attached. So, this is one kind of layout when it is a small area where sub-mains are not used. This could be another way that when the area is having divided, the main pipeline is brought to the center of the field and then on either side lateral pipelines which have been attached. This is also possible when your area is small. We did not have a sub-main pipeline. So, the field needs to be divided into a number of sub-unit. So, this could be a different arrangement, here, what we are seeing is the main pipeline is laid and then sub-main pipelines have been attached. So, we can divide depending on how much the width and then the total number of plants and what is the total area, it is there.

Then, this is one kind of arrangement, which we are seeing that so the layout will depend upon the field requirement and layout of the field. So, each sub-unit is then designed separately and operated separately having a valve at the head of the sub-unit. So, when I am telling about, this is the one case, what happened the main pipeline it comes to the center and then sub-main pipeline and from this sub-main pipeline, laterals have been attached. So, here, there are 2 sub-mains. One sub-main line goes this side. Another sub-main goes this side and this sub-main line, there is a gate valve attached. So, system layout will depend upon the shape of the field, area of the field, source of water supply, now, if everything is open to us and the well has to be dug so, it is better, that the source of water supply is to be in the middle of the field. So, that the cost of bringing water and attaching the main pipeline can be reduced.

Now, the number of sub-main can be decided, this is one criterion that total time available for irrigation divided by the time of operation of the drip system. So, we got the time of operation of the drip system, but the total time available will depend upon the number of electricity available in the region. This is another point that the number of hours when the electricity is available, accordingly, one has to see.

And accordingly, the number of sub-units, number of valves that can be operated. The layout of the drip system that is the arrangement of main, sub-main, lateral, is done considering the shape of the field, this already I have told you, size of the field and slope that which direction the mains should run, which direction laterals should run. As far as possible sub-mains should run along the slope of the field and laterals should be laid across the slope or along the contour line of the field.

So, you can see here, this is the arrangement. It is shown here. There is one lateral and then in between these crop rows are being grown. So, here, we see that lateral lines are kept between the rows of the plant. You can see here, that according to the rows of the plant, each independent one line per row, it goes adjust to the rows the laterals are laid. So, this will happen upon depending on the plant water requirement and then field arrangement.

This is the another case. There are 2 lines per row means when the plant is aged, the water requirement is high. In that case, for orchard crop, perennial crop with the water requirement is high, we can have 2 lines of the lateral for each row. This is one arrangement. The other one, we are seeing it in between the 2 rows, 1 lateral goes. So, this kind of arrangement, it is used.

So, we can see here, dripper is attached with the lateral. Here, these are the drippers and then in between the 2 rows. These are the 2 rows. There is one lateral, it goes. So, these 2 rows, the one lateral goes. This is the type of arrangement and then this means one dripper per plant and then paired row can be there, 2 drippers per plant means water requirement is very high.

Or there can be 4 drippers for each plant, where another tune is attached with the main lateral means your lateral pipeline of 16 millimeter, then there is a connector from this connector, the 10 millimeter or 12 millimeter lateral is attached and that make circular and then irrigation is being given. So, laterals are to be laid as per the plant configuration, field configuration that can be made.

So, here, the same thing which I have explained, this is given. Again it is repeated once the field layout is finalized diameter, length of sub-main pipeline, laterals for each unit are decided based on the hydraulic design of the pipeline. The spacing between the lateral depends on the crop geometry and row crops. For plantation or orchard crop, spacing between laterals is equal to the row spacing.

However, depending on the age of the tree, tree spacing and soil type, 2 drippers per row of the tree may be needed. This is what I was telling you. This kind of thing, it will happen particularly for orchard crops, which is aged and its water requirement is high. The spacing between the emitter on lateral for row crops is governed by soil type, where, in the case of plantation or tree crops, the number of emitters per tree is governed by the spacing, age, soil type. And also, one thing I want to tell here is that yes, the emitter is important, but when it is a very too close crop, then simply giving 1 dripper or 2 drippers, it is better to use micro sprinkler, so, that the wetting can be made for particularly for close growing crops.

So, we discussed all these topics.Now, you can have the closure detail, more details about this particular topic by referring to these books. This is a very important book which we can have, then you can have Larry James' book, Michael A M book. So, these books, you can refer for more details.

So, let us summarise this particular lecture. We discussed about the points which are used for the design of drip irrigation system, what should be the points that should be considered while we are designing the system. We discussed about wetting patterns and the wetting pattern it depends on the different types of soil and then the amount of water which is discharging from a dripper and then the time of application. Crop water requirement and system layout were also, we discussed.

Now, in the forthcoming lecture, we will discuss about the different types of drip emitters and how to select a particular type of drip emitter. So, thank you very much.