Water management
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Lecture No 11
Crop Water Requirements (Contd.)

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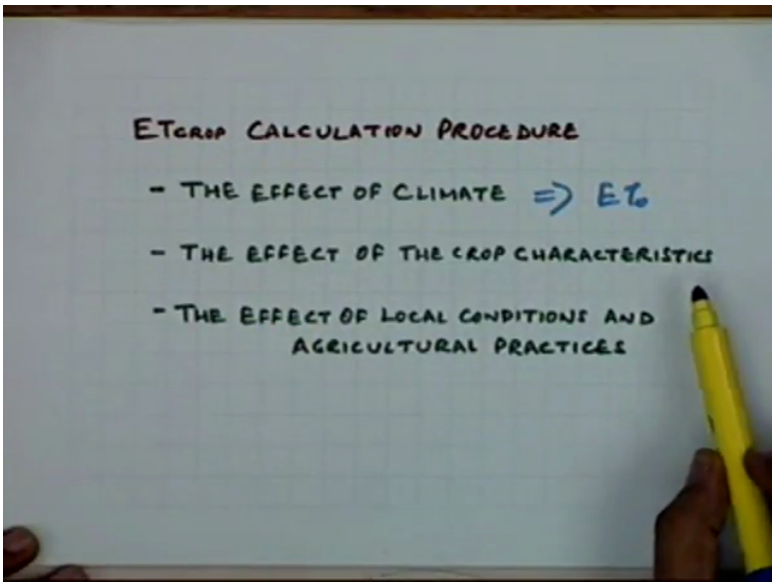

Right okay, so far we have look into the effect of climate that is the same old slide which we had shown earlier when he started with the topic of finding out the ET crop, what are the calculation procedures and we have said that we can do this by taking 3 different steps, we have already taken care of the 1st step which is the effect of climate, we had mentioned that if we can delineate the effect of climate and from the effect of the crop characteristics then our problem will be simplified that is what has been recommended by are few and we have taken into consideration the effect of climate by finding out the reference, reference crop evapotranspiration.

This has been done by taking into consideration the ET naught, so this we have dealt with in great length we have looked at all the methods which are available to find out the ET naught value and we have also looked at what is the, what are the data requirements of those methods. Having done so let us now go onto the next step which is through incorporate the effects of the crop characteristics because once we have found out the ET naught, ET naught is only references evapotranspiration which is in this particular case the way we have considered is for grass and we have taken that into consideration because of the fact that the grass can be controlled in the sense you can control the length of the size of the grass you can

ensure that all those factors which are influencing the crop characteristics they remain constant, so in the case of grass also the effect of the crop characteristics is taken care of but the only difference is that, that effect is a constant effect that is why we are calling it reference crop evapotranspiration, okay but that is not the ultimate aim, we have…

That is only a (())(3:53) media that is only one of the intermediate steps, we wanted to find out the ET crop and that too far not only one crop for different crops as when you are looking at a particular area is not necessary you have the same crop throughout the area, the area might be having growing various crops starting with the green crops, the fodder crops, they can be some tree plantations, there can be some other type of vegetable crops can be there, so all different mix of crops can be prevailing in that particular area and we want a methodology by which we can find out what is the crop evapotranspiration for each individual crop, so to attain that we had said that they are we can use these 3 different steps and we have taken care of so far the 1st step where we have found out the effect of climate in terms of the reference crop evapotranspiration, okay. Next today we will start with the effect of the crop characteristics and how we incorporate the effect of the crop characteristics into the evaluation of ET crop and that we had mentioned in the beginning that that is done by defining crop coefficient.

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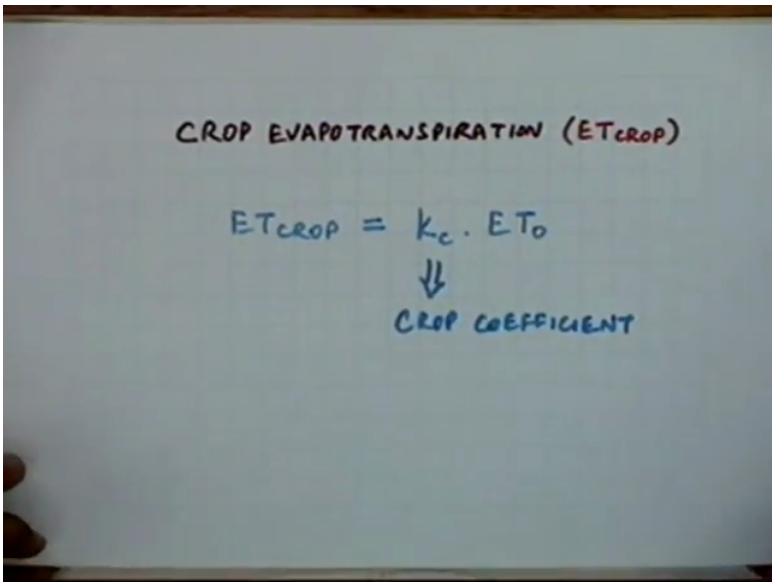

This is what is known as crop coefficient. This crop coefficient K c what we are what we are saying is that now since we know ET naught and ET naught can be related with the ET crop through a coefficient which is a crop coefficient and which can change from crop to crop will look at how much it can change, how we how we find out the values of these crop

coefficients for various crops and what are the other factors which influence this crop coefficient.

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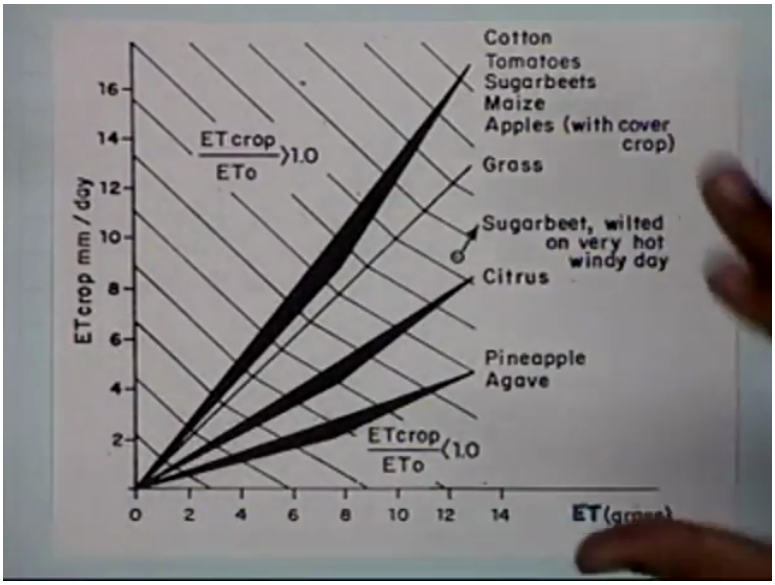

In general there is a slide which gives the overall variation for majority of the crops with respect to what you get as the reference crop evapotranspiration, now here on the x-axis we have this ET grass which is nothing but it can be used as ET 0 or ET naught, so this is the reference crop evapotranspiration. If you compare crop evapotranspiration of some other crops you will find that the variation is on both sides, there are some crops which are having more evapotranspiration requirements than the grass, there are some crops which are having less evapotranspiration requirements than the grass.

So all these this is the line which is 45 degree line and which shows the grass, if you have if you have any crop which is the ET crop of that crop, if it is falling on this line that means is equal into the ET naught or the evapotranspiration of that crop is equal to the evapotranspiration which is experienced by the grass. Look at this group which is the group containing cotton, tomatoes, sugar beets, maize, Apple this group has a value of ET crop which is more than the value of ET naught or the ET grass and that is why if you take the ratio is greater than 1, so in these crops and there is lot of variation you have to understand at this stage that is not necessary that one particular crop will have a specific level of ET evapotranspiration value is also influenced by many other factors.

So this is this is a curve or this is a plot which shows the variation of ET grass with respect to the ET crop for different crops but there is there is a lot of scatter in this variation which

accounts for many other factors which are for example the cotton of a petrol area, this species of cotton there can be many species of cotton which are prevailing, so when you say cotton is not that it will have a unique value of evapotranspiration it will also depend on where it is grown, what is the growth period of that particular crop, okay what is the sowing dates, so all those things all those factors will have a look in a moment. Now this gives you the overall picture, what can be the variation for example the pineapple and citrus, these are the crops which are having a value of evapotranspiration much less than the that of the grass under the similar conditions.

Here you are assuming that the condition the climatic conditions are similar only then the comparison can be possible. This is because of the characteristics of these crops for example in the case of a pineapple, the stomata the leaves of the pineapple are such that the stomata closes during the day time, so the loss of moisture through this stomata which takes place that has reduced considerably and that is why the evapotranspiration value is also influenced. Similarly in the case of citrus trees all the citrus trees which include the orange or all these which have the citrus qualities, all these trees you will find that the leaves are waxy, the formation of the leaves are such that the evapotranspiration is much lower, so they are hardy trees they can survive, so this species of the various crops it will be influencing the evapotranspiration rate and that is depicted in this particular slide, so this is not necessary that when you are comparing with the grass is the grass is not the one which is the lowest evapotranspiration crop, there are crops which are having much lower values of evapotranspiration.

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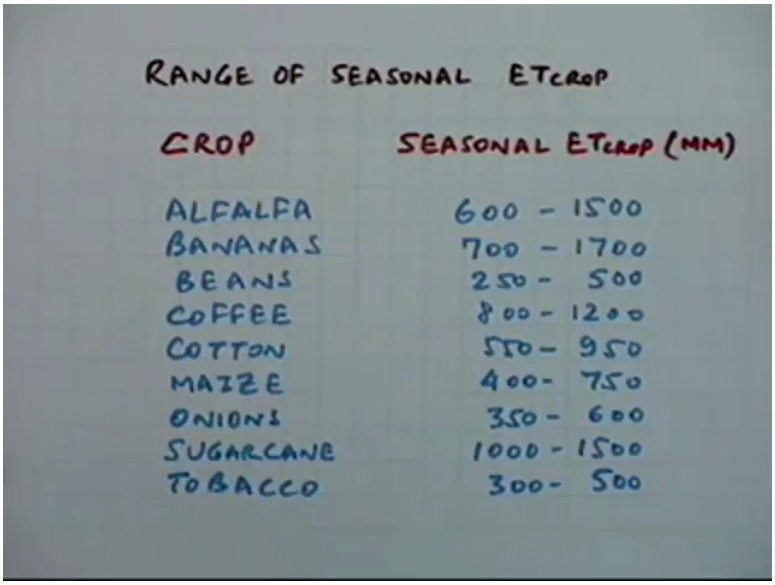

Now here I have tried to give you the range that how the ET crop varies from crop to crop, for some of the crops I have just mentioned what is the seasonal evapotranspiration requirements in terms of millimetres. If you look at Alfalfa it ranges from 600 to 1500 millimetres, here we are trying to look at the total value throughout the season of the crop. Banana 700 to 17, beans 250 to 500, so the variation is a real considerable variation from crop to crop and within the crop also you will find that with the crop if you take if you divide the total season into some separate segments which we call the growth periods or the stages of the crop growth you will again find that there are differences there, so when you talk of the K c value here we come back to K c because we that is what we are interested in, the crop coefficient is something which is not a fixed factor, is not a fixed coefficient it will change from crop to crop, it will change from stage to stage within the crop also, so that variation is what we are interested in.

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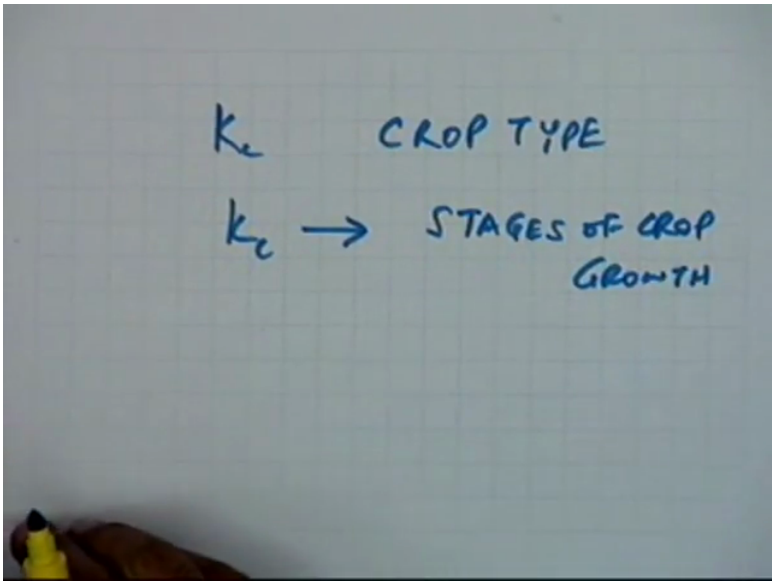

There will be a variation on K c from depending on the crop type and K c will also vary with respect to the stages of crop okay.

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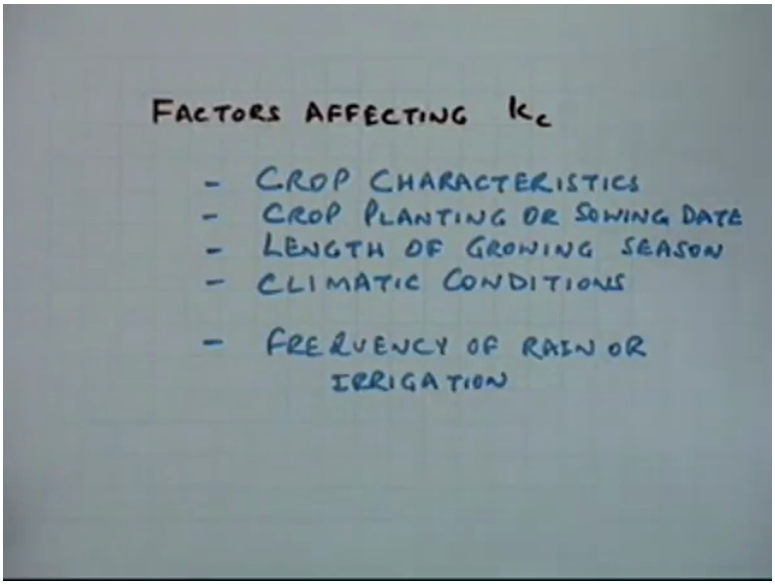

There are some other factors also which will affect the crop coefficient we have said that the crop characteristics is one factor which will affect the crop coefficient. The crop planting or sowing date; now this is a factor, what happens in a crop? If you delay its planting the whole sequence of its growth changes, it affects the whole sequence of its growth process because of the variation in temperatures because the variation in climate which are encountered in that particular area, so the crop planting or the sowing date might change the growth process of the crop and thereby the K c will also be affected. The length of the growing season again different under different environments you will find that the same crop might be having a different growth period.

The climatic conditions, how do they vary? We have looked at the impact of the climatic conditions on the ET naught but again it depends how we are considering those climatic conditions, are considering them on the average basis? Are we considering them on the actual basis? So those climatic conditions their variations will have some impact on the K c values which will again will have a look at each of these factors how the effect and the frequency of rain or irrigation that means the availability of water. What is the moisture availability in the soil?

That will influence the K c values because K c value is nothing but is a factor which is relating the evapotranspiration with some base evapotranspiration which is the ET naught, so the opportunity of evaporation evapotranspiration, evaporation as well as transpiration, this opportunity will be dependent highly on the availability of moisture that we have seen in the case of our topic where we have tried to look at relationship between the crop, the water and

the soil and we have seen that how the stresses change or the moisture utilisation changes with the availability and all those things, so the availability of rain or the irrigation water and the soil are the moisture of moisture availability in the soil will influence the K c factor also.

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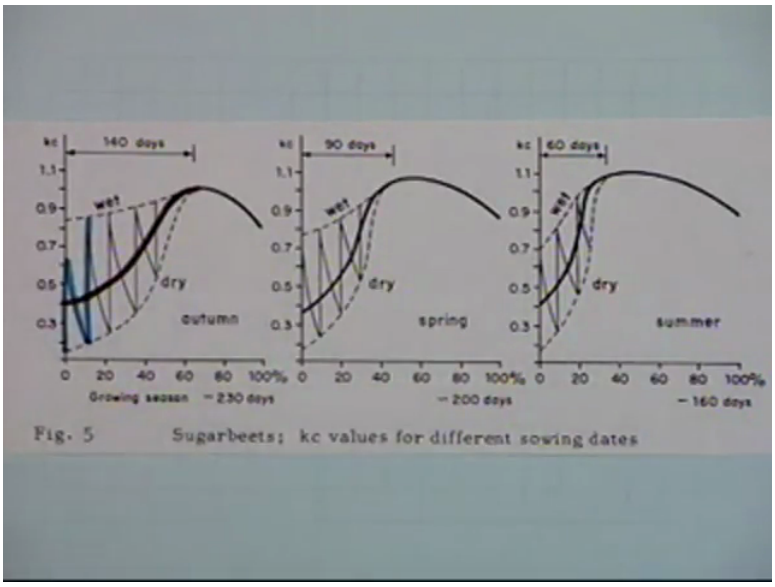

Fig. 5 Sugarbeets; kc values for different sowing dates

Now here one example has been taken to highlight some of these factors, this is the case where sugar beet is the crop and K c values have been shown here for the same crop but having different growing seasons. Now this is the sugar beet which is grown in the autumn and spring and summer, now in all these 3 cases the total growth period is different, in this case it takes 230 days of the sugar beet and in this case 200 days and in this case 160 days and this is because of the fact that their climate is different and within this for each individual case you will find that here it is depicted that how the K c actually changes when you make the water available.

So when the conditions are met suppose you have given the this is the initial moisture condition, this is the initial moisture level, now the K c will keep on varying the actual coefficient will keep on varying with respect to the moisture availability, it will keep on reducing as the moisture reduces because in that case what happens the evapotranspiration activity is influence because of the moisture availability, the moisture is not available through the potential is there for the moisture to deplete the soil but the crop is not in a position to make that depletion possible because of the higher stress because of the deficit which is available in the moisture in the soil.

Thereby that is that is taken account of by the K c factor, so the K c is the one the crop coefficient value reduces, so again if you apply this is the amount of irrigation water you have brought the level up to a level which might be close to the field capacity level, so you have applied another irrigation at this particular stage again the K c value goes up and the same continues, so if you keep on applying more irrigation or this natural rain then you will find that this K c will fluctuate with respect to the moisture availability of the soil and this is the firm line which is shown here, this is basically the average value of K c because in actual practice when you using these values it might not be possible to keep track of the actual moisture conditions, you are your trying to use a value which is an average value of K c and this gives the variation of K c and this total growing season, okay.

Now in the other case you will find that this particular case the time for majority has reduced, so the same thing is also true in this particular case also in the 3rd case also is the same, trend is same but the time to maturity is much reduced because of the different climatic conditions, so that happens and it happens because of the various, in this case it happens because of the moisture availability, it also happens because of the different species of the same crop or under different climate and you will have to find out the K c values which are relevant values which are appropriate values under those conditions, so that is what is the important factor which you will have to look at.

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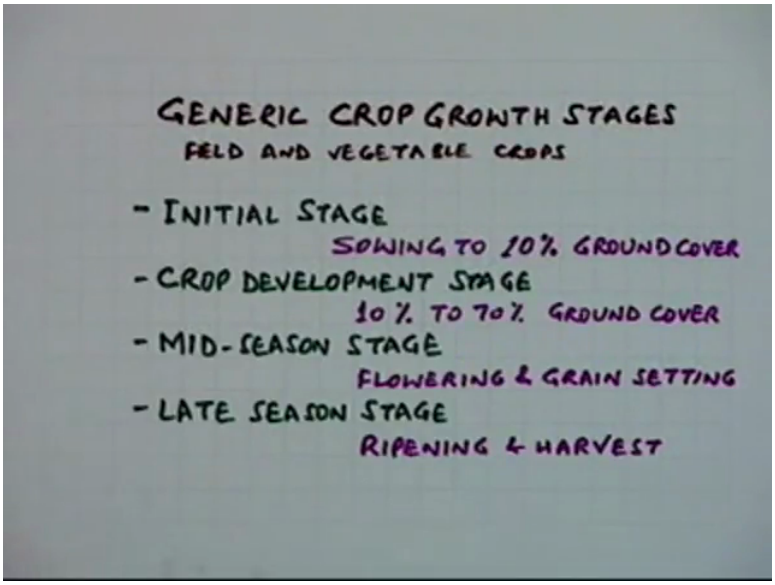

Now this is again the same slide which we had looked at earlier that in the case of field and vegetable crops, in general we can divide the total growth period of crop into 4 stages; initial stage, the crop development stage, the mid-season stage and the harvest or the late season

stage. Now these 4 different stages, in literature you will find that these stages the data are available for most of the crops, what are the various stages? What are their lengths? And if they are not available in the local universities or the local researchers organisations which are indulging in this particular area of agriculture they will have those values.

So these are the values which are not difficult to get once you have these values, the data on these basic growth period of the crops you can develop the K c values using the various procedures which are recommended by a few. It has been found that for these 4 different stages or let us 1st discuss only for the field and vegetables crops because the evaluation of K c values for other crops which are having different characteristics is also different. There is this (())(23:28) 24 which we are referencing for this particular purpose it has all these details given they have recommended the growth period for different crops under different conditions and they have tried to cater to the total requirements around the globe and they have also given procedure which should be used to construct your own K c values or your K c variations when you use a particular crop, so that is what we are trying to look at.

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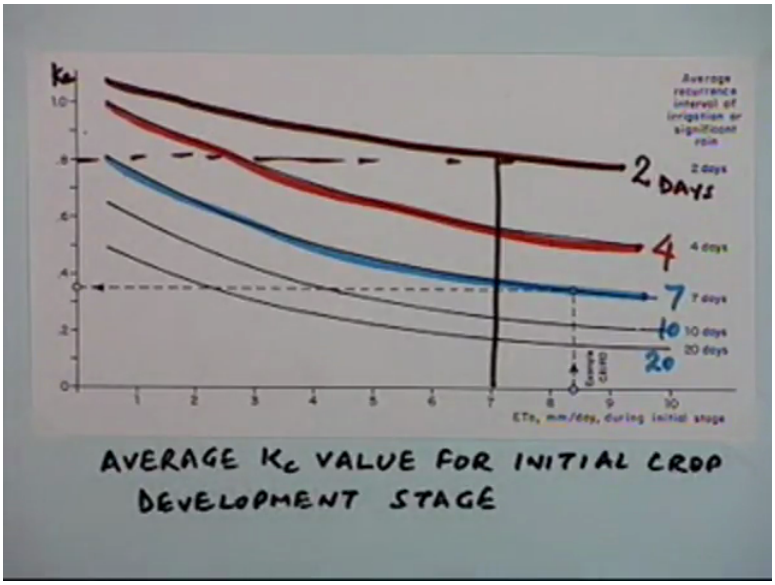

Now this is the graph which gives the average K c values for initial crop development stage for the field and vegetable crops, the very 1st stage gives the values which are function of at which frequency you are making the moisture available, let's look at the initial stage, what happens in the initial stage? Your only activity is the activity of sewing, the size of the plant will be very small at the end of the stage also, so which is the activity which is the most important activity during this period is basically the activity of evaporation, there is hardly any transpiration which becomes the part of the total evapotranspiration, so the

evapotranspiration is predominantly governed by the evaporation activity evaporation from the soil and is quite obvious that the evaporation from the soil will be a function of the moisture availability in the soil whereas in the in the other cases when the crop grows and the land or the soil on which the crop is growing in some cases it might be totally shadowing the land, so there will be the reduction in the evaporation activity will be taking place as the crop grows.

There are the canopy formation will be there of the crop and it will also depend on what is the type of crop? How much shading it can or how much coverage it can give to the ground? But in general you can visualise that the activity of evaporation will reduce as the time passes or as the you go into the next stages of the crop growth but in the beginning in the very 1st stage the major activity will be the activity of evaporation that is the reason that the average occurrence of irrigation or the availability of the natural water through rain will be the first… will be the governing factor in the case of the initial stage that is what has been recommended here that and the in this particular stage the K c values versus the ET naught in millimetres per day during the initial stage that has been plotted and is varying with respect to the average recurrence interval of the rain or of irrigation.

Let us have a look this top curve, it belongs to recurrence interval of 2 days whereas the next one is the four-day recurrence interval in the next one is 7 days and so on, this one is 7 days the next one is 10 days and 20 days. Okay in this case now let us have a look, what we are saying indirectly is that if you are making the moisture available very frequently then knowing the reference crop evapotranspiration for this a K c value will be very high value, so if you have if you have 7 millimetres per day as the ET naught value and your moisture availability is every 2nd day you are making the moisture available either through irrigation or through rain fall as the material then the K c value will be 0.8. On the contrary if the if you are making the water available after 7 days and the ET naught is the same 7 millimetres per day then your K c value is 0.6 is low ahead because of the reason that the evaporation activity will be much less.

So since that is the dominating segment of the ET crop, so your ET crop will be much less if the moisture available these less the ET crop will be less and that has been taken care of by this particular graph, so lower the reference interval of the irrigation or rain you will get a lower K c value because the evaporation activity will be influenced will be much difficult for the moisture to leave the soil through evaporation and thereby it will influence the K c factor,

so the K c value will keep on reducing, okay. So using this representation you can find out what is the K c value for the field and the vegetable crops and during the initial stage of the crop development.

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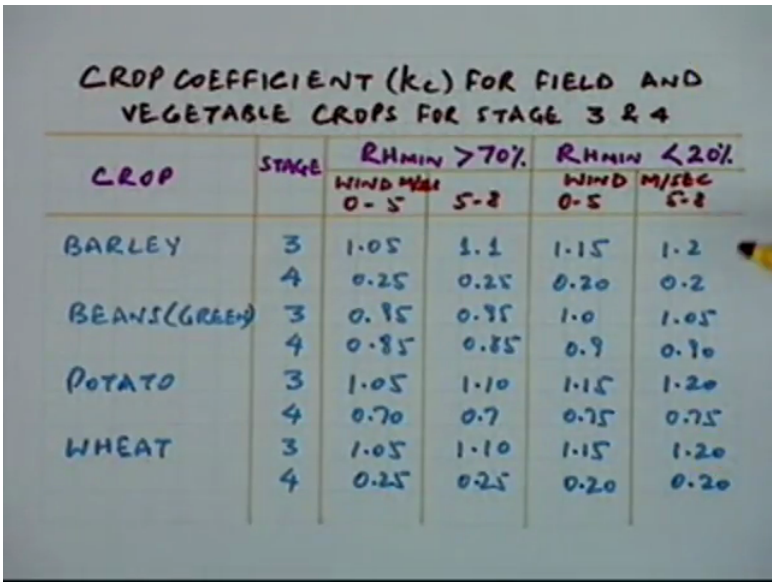

For the remaining stages for stage number 3 and 4, these are the stages when you are towards the majority you are at a level when the crop is fully mature, these stages are influenced by the relative humidity and the prevailing wind, so there is a relationship which has been given, it has been recommended after they have collected the data from all over the world they are recommended these values for different climatic conditions and I have just picked up some of the values just to show you that these are the tables which are available, you can refer to (()) (31:30) 24 and I will also make the table available to all of you, all these standard tables which are available (())(31:38) 24 I will provide you a set and that can be these can be used, so in this case now for Barley for stage 3 when the wind is between 0 to 5 metres per second and relative humidity is greater than 70 percent you are having a value of K c of 1.05 the value changes to 1.1 if the wind speed is higher is between 5 and 8.

Similarly if the relative humidity was lower it was less than 20 percent then your K c value would have been higher because there was this more absorption capacity in the air they can be the activity of evapotranspiration can be enhanced and that is why that can be taken care of by a value which is a higher value of K c. Similarly if the wind is again of a higher magnitude then you will still get a value of K c which is higher than this value or these values also. Similarly you will find that between the stage 3 and 4 there is a drastic change and the case of stage 4 this is the last stage when the crop is mature as the stage which is the

harvesting stage, you will find that the requirement of evapotranspiration reduces drastically because the crop does not need that moisture any further and it goes down from 1.05 to 0.25 but it will again there is no hard and fast rule is again a function of which crop you talking about? What are the characteristics of the crop?

If you look at between Barley and beans in this case the K c value has reduced from 1.05 to 0.25 whereas in this case in the case of beans it has reduced only from 0.95 to 0.85, so the reduction in the K c value is the function of which crop you talking about? What are the characteristics of the crop? How much is the moisture requirement of the crop? And that is depicted very well depicted here most of the green crops you will find that the requirement reduces drastically for example in the case of wheat also from 1.05 it goes down to 0.25 but in the most of the vegetable crops you will find the difference between the stage 3 and stage 4 are K c values means they might not be that much different and the variation will be very final variation. So which shows, which indirectly dictates the water requirements, we are looking at we have the ultimate aim is how much irrigation water you will need if the natural water is not available, so these things will throw light on the requirements because you should supply that much as it is required and that is what we are trying to go through in this total process.

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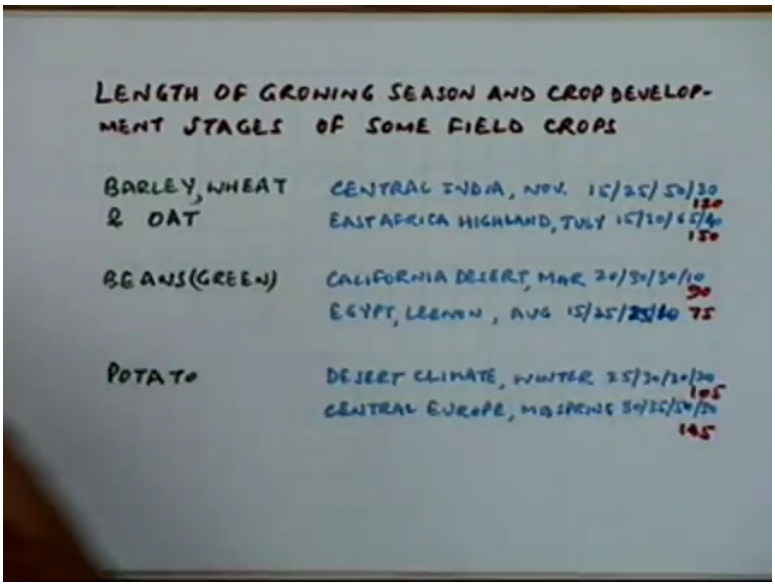

So suppose this is what I was referring to that this is again I have picked up the length of growing season and the crop development stages of some of the field crops. These are the crops which I have just taken the barley, wheat and oat they have the same growing length growing season length but they vary from if you talk in terms of the same crop but they are

being grown in different environments than their lengths can also change that is what we have seen in the case of central India, the wheat is grown in November and these are the lengths of 4 stages.

The 1st stage 15 days length, 2nd stage 25 days for stage 50 days and the 4th stage 30 days, so the total length of growing period is 120 days but the same wheat or barley when it is grown in East Africa in the high land, the month is July and the length of the different growing stages, the change is 15 the same in this case but this is gone to 30, this is 65, this is 40 and the total length is now 150 days in place of 120 days which we see in India. Similarly in the case of beans for different areas all this is made available by a few they have compiled this data and they have consolidated this data and that data is available, so the length of the growing season is also something which is available with you, you can use that information to construct the variations of K c.

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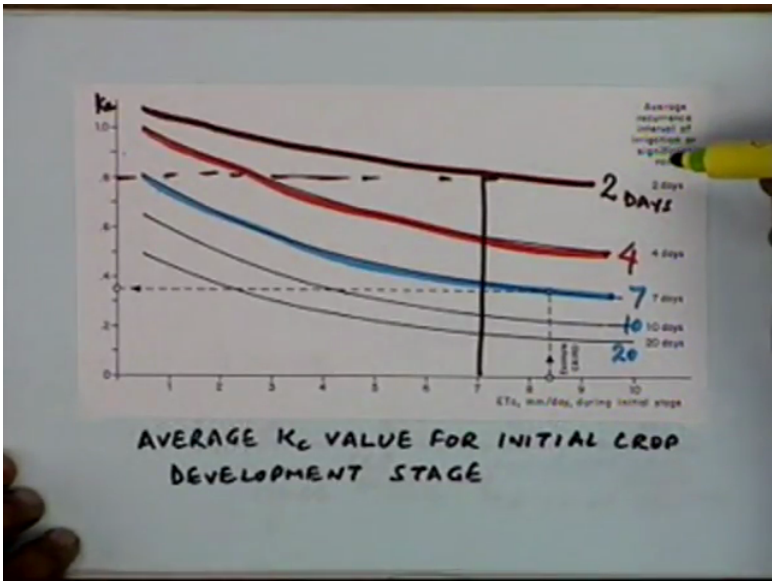

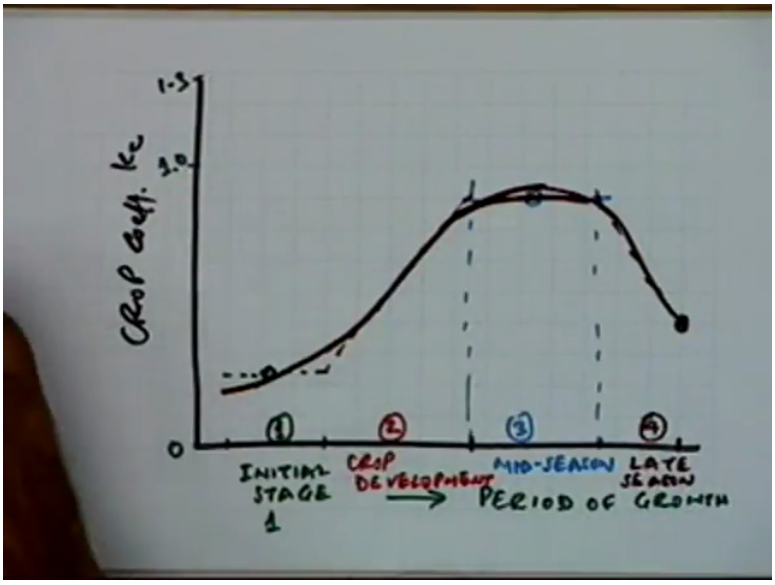

Now having done so let us look at how we proceed, suppose this is…now this is the we have seen that the if we represent the period of growth of the crop and we can mark that this is the period, this is the initial stage or stage 1 of a specific crop. Any crop you can choose and then the next stages is the, the 2nd stage is the crop development stage, so you know the length of this stage also in terms of days is number 2 then you have the mid-season, mid-season stage and you have the last stage which is the late season stage, now having known these 4 durations which we have found that they are available for a specific area for a specific crop. Once we knows these we can then the recommended procedure is that here we are going to find out the crop coefficient this is what we are interested in knowing at how this varies from stage to stage or for this total period of the crop. How the K c value varies? We have also noted down that the K c value for this initial stage we are we know that there is a value which is available depending on depending on this variation which we have just looked at in the initial depending on the recurrence interval, if we know the climate if there is rain which is the input or if the input is the irrigation then what is the recurrence interval of that irrigation which you are using in that particular area knowing that and knowing the ET naught because ET naught is already computed using one of the methods which we have recommended, so knowing the ET naught and recurrence interval of the moisture availability, we can read out the value of K c during that initial stage.

So suppose this is the value which we have obtained and this value will be you can say that this varies from 1.3 and in between this is the scale which is used, so on that scale you find out what is the value of K c during this initial stage and we can assume that this variation is

throughout this initial stage the K c value remains similar or remain same during that stage that is the assumption which is made here and constructing this variation.

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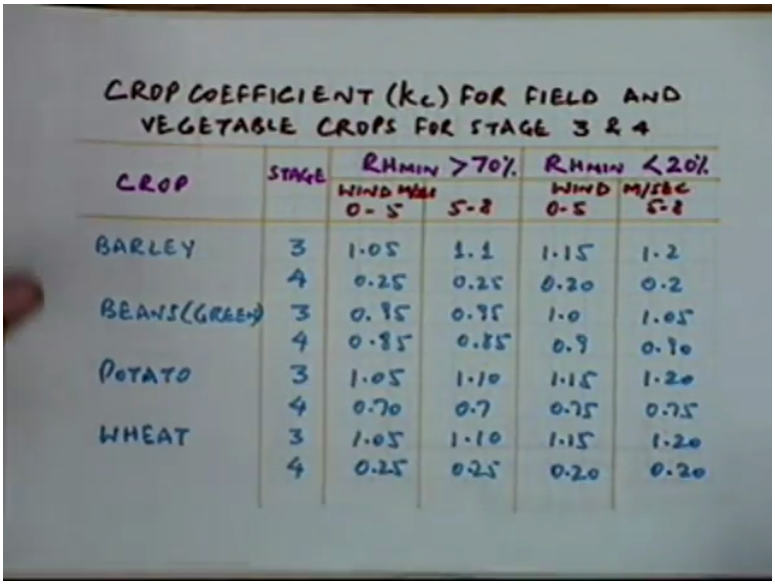

CROP	STAGE	RH_{MIN} >70%		RH_{MIN} <20%	
		WIND M/SEC 0-5	5-8	WIND M/SEC 0-5	5-8
BARLEY	3	1.05	1.1	1.15	1.2
	4	0.25	0.25	0.20	0.2
BEANS(GREEN)	3	0.95	0.95	1.0	1.05
	4	0.85	0.85	0.9	0.90
POTATO	3	1.05	1.10	1.15	1.20
	4	0.70	0.7	0.75	0.75
WHEAT	3	1.05	1.10	1.15	1.20
	4	0.25	0.25	0.20	0.20

Then we come down to the late-season stage and the late-season stage we have again seen that for the specific crop which we have which we are looking at we can use the information available and find out what is the value of the K c values for the specific environment if we know the RH minimum, if we know the wind speed we can find out which is the value which is the relevant value for stage 3 as well as for stage 4, so those 2 values are known and we can draw them in the form of those 2 points this is 1 point and in the case of the stage 3 there is another point which we can say that this is the point, the values which are corresponding values which we can read from the table, so these 2 values are written down.

Now the recommended procedure is that we draw a line parallel to the x axis from that point which is for the mid-season stage so, so we draw horizontal line through that point for the total mid-season stage and for…this is the that is a stage total stage and then we join these. This is the end of the initial stage we joined this and this and on this side we joined this and this, so this K c value is plotted at the end of the 4th stage and you join the point which is corresponding to the end of the mid-season with that point.

Now this gives you a variation and then you can even because you know that the variation is not occurring in this manner there is an abrupt peer some abrupt changes which can occur in nature, so there has to be some smooth transition one stage to another stage or you can draw an approximately a shape which is smooth curve between these points or you can even have

it…so this is the variation which you can take as the representative variation of K c value, okay and this can be used this can be constructed for any crop which is the vegetable or green crop and you can use these for known values what we are assuming is that between this stage initial stage and the crop development the mid-season stage, during the crop development stage there is a variation of K c value from our known value of K c during the initial stage up to the mid-season stage and we are trying to use that because this is a very steep change and during the other periods we have some representative values available we are making use of those values to give a uniform variation which can be used now to find out how the crop evapotranspiration will vary from stage to stage within the same crop.

On the contrary if you want to use a mean value for the whole season of the crop even that can be done by taking a representative value which is the mean value of this variation but it depends on what is your requirement for example if your requirement is to go in for the design of irrigation system where you are looking at the values which are to be used on the average basis whether that time when you are going for the design you have to look at many other factors one major factor is size of the dissolution system. If you try to cater to all the requirements in terms of the extreme requirements you might find that your size requirement of the carrying of the carrying capacity in the form of carrying capacities of the channel or the canal will become so huge that it might not be economically viable.

So if that is the requirement then you might have to look at some average values you also have to bring in the risk factors. Do you want to take care of extreme values always? Which means that even those situations which are which are experienced very infrequently maybe once in 10 years or once in 15 years if you take care of those extreme situations, extreme climatic conditions then you had it because then the requirements of from the system requirement point of view they will become very huge whereas if you are interested in utilising this information in deciding what are the actual requirements in terms of the scheduling of irrigation, when you try to find out what are the requirements at a particular location of irrigation and you might need the actual values of K c, how do they vary from time to time? Because when you talk of irrigation requirements how much water is needed? You are talking in terms of the known climatic conditions.

Are you here and what we are saying is that when you are giving the irrigation are you at this location in time or are you here. If you are here your requirements are very small in comparison to what will be the requirement when you are here, so that is what the total

business of scheduling is at how much requirement of water is there? How are you going to supply that in what quantities at what timings? That we will come to...At this stage I thought it would be better if we can put some thinking in terms of how are we going to utilise this? What significance this K c variation has in terms of water management, okay. Any question? Thank you then we will stop here and tomorrow we will…