Design of Farm Machinery

Prof. Hifjur Raheman
Agricultural and Food Engineering Department
Indian Institute of Technology Kharagpur
Week – 08

Lecture 39 : Granular chemical applicators

Hi everyone, this is Professor H. Raheman from the Agricultural and Food Engineering Department. I welcome you all to this SWAYAM NPTEL course on Design of Farm Machinery. This is lecture 39, where I will try to cover granular chemical applicators. The concepts to be covered: components of granular chemical applicators, classifications of granular chemical applicators, the working principle of granular chemical applicators, and the functional processes of granular chemical applications.

Why do you require chemical application? The main aim is to apply agricultural chemicals to provide nutrients to plants for their growth and to control weeds, insects, and plant diseases. Now, what are the different chemicals related to agriculture? We call them agricultural chemicals. So, fertilizers, pesticides, fungicides, herbicides, and other growth-regulating chemicals are called agricultural chemicals. These chemicals are available either in dry granular form, liquid form, or powder form. So, these are the three possibilities by which these chemicals are available. The dry chemicals in agricultural use are primarily fertilizers, herbicides, and insecticides. The granular pesticides are liquid chemicals impregnated on inert granular carriers. These carriers could be clay, sand, or corn cobs. So, inside those carriers, the liquid chemical will be available.

Now, let us see what are the advantages of applying dry granules? Why do you apply dry granules? What are the advantages? The number one is it eliminates the need to mix water. We do not have to mix water with chemicals. Drift is not a problem drift means the target area when we try to carry out spraying target area is not covered if there is wind that will be shifted to some other areas. So, that is called drifting. So, drifting is not a problem as we do not add water, only we try to drop the dry granules. Then this application equipment is less expensive. It is obvious there is no machine required to mix water with chemicals. So, we do not require any pumps or agitating systems. So, that is why the application equipment is less expensive. It is safer to handle than liquid chemicals, you are not the person who is going to distribute this. The operator is not in direct contact with the chemicals, he may be in contact with those granular materials, but inside which the

chemicals are present. So, there is no direct handling with the liquid chemicals, hence it is safer to handle. Then the disadvantages which are associated. Granular metal is more expensive than the liquid chemicals. Granular material has poor metering characteristics because these are hygroscopic in nature, it absorbs moisture. So, there is a free-flow problem. So, that is why the metering characteristics of granular metal are very poor. The use of granules is limited to soil application; you cannot apply them just like spraying. Now we carry out spraying over the leaves, over the crops, but you cannot put it on the crop either; it has to be applied to the soil surface. So, that moisture is there. So, then the fertilizer will be activated, or the chemicals will be activated.

Then, the granular materials must be kept in a dry place, and they are more bulky. So, handling and storage is a problem. So, these are some of the advantages and disadvantages. Next, with an increase in the concentration of active ingredients, there has been a shift towards smaller granular particles. That means the nano, nano urea - you must have heard about nano urea. So, that means the concentration of active ingredients is high. So, you can go for smaller particles. So, smaller particles will tend to have better coverage. So, you can cover more area by increasing the number of particles per unit area. But when you go for liquid chemical application, this number of smaller particles is a problem that means there will be a drifting problem; the smaller the particles, the higher the tendency to drift.

So, how do you apply this granular liquid - granular chemicals or granular chemicals - agricultural chemicals. They can be applied before planting, they can be applied after planting, they can be applied during planting. So, before, during, after, after means after plant has grown up. So, let us see how do you apply before planting. Application before planting - so, usually what we do is we apply the material either on the soil surface or placing it below the soil surface. So, if you want to place it below the soil surface, then you have to have some appropriate tillage implement. If you want to apply on the soil surface, you just broadcast it or distribute it and then you have to have some tillage implement, so that the soil will come in interact with those granules. So, you have to have interaction between soil and granules. So, you have to have some tillage implements to apply the granules before planting if you follow that method. The material which is applied on the surface this has to be incorporated into the soil using an appropriate tillage tool, otherwise it is of no use. The ammonia for example, it will be lost. So, we have to have some tillage tool to make it interact with soil. Then the other method is application during planting. This is the most commonly done fertilizer drills and it is mostly done. This application during planting is mostly done while carrying out with the use of a fertilizer drill. So, when you

use a fertilizer drill obviously we have to have a hopper to store the fertilizer or the dry granules and then you have to have a tube through which those granules will be falling on the furrows and then you have to have furrow openers. through which those granules will be falling on the furrows and then you have to have a furrow openers. These are the things which should be available in the equipment if you are going to utilize the fertilizer drill. And where do you apply? You cannot apply directly on the seed, you have to apply on the sides of the seed - seed rows and below the seed. So, that the roots can extract that one it does not come in direct contact with the fertilizer. Similarly, you should have row cup planters with attachments to place fertilizers in narrow bands on either side of the seed row. You can have seed cum fertilizer drill, there is another possibility so that you can place the seed as well as fertilizer side by side. The furrow openers for fertilizer are separate from the seed furrow openers that means, you cannot drop both seed as well as fertilizer in the same furrow as I said. So, you have to have two different furrow openers and they can be adjusted independently, that is another requirement in the vertical as well as horizontal directions.

So, usually the fertilizers are applied 40 to 100 millimeter away and 25 to 75 millimeter below the seeds. So that it does not come directly in contact with seed. Then the third method is application in established crop that means, after planting when the crop has grown then we can apply this dry granules. So, chemicals are put either on the surface or below the surface of the soil. So, the method of application again depends on the crop and the planting procedure which you followed because we can have row to row planting, you can have solid planting. If you have solid planting, it is difficult to utilize any tillage tool because seeds are present here and there. So, it depends - the application method depends upon the crop and the planting type. In solid planted crops, fertilizers may be surface-applied using either a drop type or a rotary spreader. Then, subsequently, you cannot utilize any tillage tool, as I said in the beginning. Now, if you are applying in row crops, then it can be applied in bands, on the sides of the crop rows between the two rows, or it can be applied on the side of the rows, which is called side dressing. That means you can apply on both sides. So, that means between the rows, you have to apply.

Then, let us see what are the different methods for the application of granular chemicals. The two methods are the broadcasting method, and the other one is banded application - that means you have to apply fertilizer in bands in narrow rows.

The equipment for applying granular material is divided into three types: one is the drop type, which is gravity-fed; the other one is the rotary type, which uses centrifugal force;

and the pneumatic type, which utilizes air. Now, let us see what is a drop-type fertilizer distributor? So, the figure I have indicated here is a drop-type fertilizer distributor. You can see the hopper here - it covers a wider range and the fertilizer is falling on the ground through the different openings. They can be used either for broadcast application or for banded application. If you want to apply throughout the field, you can have a number of these openings. So, you can see from here to here everywhere at regular intervals the fertilizer - fertlizer granules are dropped. You can see from - starting from here to here. So, then the problem here is you have to have a hopper, you have to have an agitator, ok. So, that it agitates the fertilizer which is present inside the hopper and then you have to have an orifice through which the fertilizer should drop. So, that by varying the size of orifice we can regulate the application rate.

The tractor drawn units they have a long hopper starting from 2.4 meter to 3.7 meter with a narrowly spaced opening in the bottom so that at each opening you will get fertilizer. So, that opening can vary depending on the application rate. So, a ground wheel driven shaft has to be located inside the upper near the bottom, so that it can agitate. So, agitation can be taken up by taking power from the ground wheel. This agitation is required so that the fertilizer can freely move there is no breezing action in the outlet.

So, then question arises how to - how to control the application rate here - by providing a slide gate, that means, we have to increase or decrease the opening size of the orifice. So that we can control the application rate and also during turning you can close it. So, you have to have a sliding device - sliding gate so that we can control the flow from the orifice. Whenever you do not require you close it. Whenever you require you open it. And when you require what is the quantity required that has to be regulated by regulating the size of the opening.

Then comes, drop type applicator for banded application. The previous figure, where you can see the width of coverage is greater, but this kind of applicator is used for applying fertilizer in bands in narrow areas. So, it has a hopper to store the fertilizer and a metering device. Then there is a discharge tube, and at the end, there is a diffuser so that it distributes. So, a drop-type applicator for banded application utilizes several small hoppers compared to one long one; you have to have smaller hoppers instead of longer ones. Then the material is metered and dropped through a tube, just like a seed tube in a seed drill. You have to have a tube through which the fertilizer is dropped and spread in a wider band by a diffuser, which is the triangular area here.

Then some fertilizer distributors have furrow openers to place the material below the surface. That means if you want to put fertilizer below the surface, you have to have a furrow opener. Then this type of spreader is most commonly used as an attachment to planting equipment. So, depending on the number of rows, you can have a number of such units. So, the power source will decide how many rows you have to cover and also what is the maximum width you can handle during turning. These are the two factors which are to be considered for deciding the number of such units.

Then I will show you a truck-mounted commercial rotary applicator, which means we apply or distribute fertilizer with the help of centrifugal force. The hopper is connected to a plate which is rotating at a certain RPM, and the granules - the chemicals will be available to this rotating plate. So, the rotating plate will distribute the material because of the centrifugal force. So, this is used for broadcasting; it cannot be used for banded application. These spreaders have one or two rotating disks with multiple vanes, so that it imparts energy to the granules. So, this centrifugal force which is applied to the granules or because of the centrifugal force these granules will be distributed. The material is metered onto the disk - rotating disk and is thrown wide due to the centrifugal force. Then the rotary spreaders are generally tractor mounted, but in some of the larger commercial units you can see the the trucks are also used to carry out this exercise, but the tires which are provided with the trucks are floating tires. You can see in the figure there is a truck this is not a tractor.

Then the third unit is pneumatic applicators, pneumatic applicators they can be used for either broadcasting or banded application, this can be used for both. So, they have a centrally located hopper from which granules are metered. and they will be delivered by air through tubes. So, that means, there will be flow of granules and the granules should be carried by the pneumatic system that means, by air and it will be carried to different units present. If you look at the figure you can see there are different deflectors here. So, in all these deflectors, the material should be available. The granular material should be available and the granular material is forced to pass through these tubes, the black tubes. Then the pneumatic applicators allow - they allow central tank filling and the easier installation. So, it becomes easier for installation on tillage implements, improved distribution and in easier transporting of trailer mounted applications.

Sometimes aircrafts can be used to broadcast fertilizer. So, why do we use aircraft - when the area is too large or the terrain is such that it is not reachable, reachable in the sense it is difficult to reach there to carry out some operations, so, there we go for utilizing aircrafts

for broadcasting fertilizers. So, where the areas are either too large or too difficult (that difficult in the sense rough terrain is there or flooded rice field is there) for ground rigs, we can go for utilizing aircrafts. But, the limitation is the payload, how much it can carry? So, 500 to 1100 kg it can carry and it can work at the speed of 130 to 190 kilometer per hour. So, that means, the area should be very large then only it is preferable to utilize aircrafts. The height of application also varies it varies from 9 meter to 15 meter, the only problem is the uniformity. Uniformity of application is also severely affected because of the high speeds of movement.

Then rotary spreaders are also used in aircraft planes. In aircraft applications you can also use rotary spreaders. The spinners used in aerial applications rotate at a much faster speed as compared to the ground rigs in order to cover a much broader swath. That means, by rotating the rotor - rotary broadcaster you can say at a higher speed, you can cover more area which is not possible for a ground driven unit. You can also use helicopters. But the operating cost of helicopter is 2 to 3 times higher compared to fixed wing aircraft. So, now these aircrafts or helicopters they are not generally used, they are used in limited areas where you have bulk of land which is grown for the same type of crop or the areas - high hilly areas. So, where the persons or the machines are unable to reach. So, then we go for that one.

And let us now see what are the functional processes of granular chemical applications? So, we saw some different granular applicators, then what are the functional processes involved?

The first one is your metering, which means after storage, it has to be metered. Then after metering, it has to be conveyed. From conveying, it has to be distributed. Only conveying will not help; it has to be distributed. Then after distribution, it has to be placed - placed in the soil or below the soil. So, these are the four important functions to be carried out by a chemical applicator. Metering - metering means it includes the storage of fertilizer. So, metering, then the granules or the fertilizer that are stored have to be conveyed to the point where they will be distributed. After distribution, they are to be placed in the proper place. So, the metering unit - there are different types of metering units available. The target is to obtain consistent and uniform metering of granular materials. So, usually, the metering units are driven by a ground wheel so that they stop metering when the implement is lifted or when you are taking a turn. Then, the metering devices may be divided into two types: positive flow type and gravity flow type. So, let us see now what is this positive flow type, what is gravity flow type? In the case of a positive flow metering device, it provides more

accurate metering because we are forcing a certain quantity to be dropped. That means you have to create a space, which is called a cavity. That cavity is used to meter a certain volume of fertilizer, and the rate of movement of that cavity determines the metering rate. Now, the gravity flow devices rely only on the orifice - orifice means orifice size. So, if you want more, we increase the orifice size; if you want less, then we will decrease the orifice size. So, by opening or closing the orifice size, we can control the flow rate. The figure which I am showing here is a rotating bottom metering device. It is a horizontal rotating bottom plate which is fitted against a stationary bottom ring of the hopper base, and there is an agitator provided - the blade you can see there is an agitator. The discharge rate is controlled by an adjustable gate. You can see there is an opening here through which the granules will go out and by increasing that size or decreasing the size you can control the discharge rate. Sometimes you can have two outlets or three outlets depending on the capacity, capacity of the metering unit.

Then, we can have a star wheel, star wheel metering mechanism - is a positive metering mechanism. The star wheel feed metering device - the star wheel feed metering device is used on some grain drills - we have already discussed - horizontal plate planter. So, similar to star wheel and a few row crop side dressing attachments. So, this type of metering device can also be used along with some grain drills to drop fertlizer. The fertilizer is carried between the teeth you can see these are the spaces through which the fertilizer will be carried. On the top of the wheel is excess fertilizer - will be scrubbed off and the discharge is controlled by controlling the gate opening. That means, you raise it or lower it above the wheel then that gate will reduce the flow rate.

Then the other positive metering unit could be an auger. Close fitting auger or loose fitting auger. If you look at the figure this is a close fitting auger, you can see auger is here. It is fitted inside a pipe and there is opening through which the grain - the fertilizers will be available and due to movement of this auger, the fertilizer which is coming on to this pipe they will be carried to one side that is the concept. So, it will take fertilizer from one side and drop it on the other side. Then the other figure which I showed this is a metering device that is an auger type metering device with loose fitting. Loose fitting means there is a gap, gap of 12.5 millimeter. So, the pipe inside which the auger rotates, the diameter is 12.5 millimeter greater than the diameter of the auger. So, there are two augers - auger sections, they move material towards one end of the hopper where it is discharged from the end of the tube or dropped through an outlet opening. So, if you look at the figure, see this is one arrangement, this is another arrangement. Here, the fertilizer is coming from the top of the

pipe there are openings through which fertilizer will enter and inside the pipe the auger is rotating and at the bottom side there are openings. So, the top side it is getting the input and then bottom side it is getting the output. So, the rotation of the rotor of the auger will decide and the size of the auger will decide what will be the flow rate. One hopper serves two rows and these augers can be easily removed for cleaning that is another advantage. Materials that enter the auger from the top as I said it is entering from the top instead of from the end. In a close fitting it is entering from the end, in a loose fitting it is entering from the top. Then it is transported to a certain distance through the chute and is then discharged from a bottom outlet. ok. The tube assembly forms the bottom of the hopper and it is removable. A series of opening along the tube will provide multiple outlets for row crop use. So, if you want to use it in a row crop, then you have to have openings at a distance matching with the row to row distance. So, you have to maintain those openings at row to row distance, so that it falls in between the rows. With any of the auger type metering devices the discharge rate as I said will be adjusted by changing this speed ratio, speed ratio between the auger and the ground wheel. The power is taken from the ground wheel. So, if you can change the ratio, you can change the metered quantity.

Then this is an edge cell type just like in a fluted roller, it is called edge cell vertical rotor metering or vertical plate planter you can say the same, principle is same and edge cell positive metering device are spaced along the hopper that means, the number of such units will match the number of rows then it will be driven by a common shaft. And the width of this plate varies from 6 millimeter to 32 millimeter depending on the discharge rate. As I, as we discussed during seed drill that how to vary the seed rate in a seed drill? we vary by changing the length of the flute or by rotating the flute. So, rotation is not allowed in the sense it may damage the seed. But here same thing. We also follow the same thing, the length of exposure has to be varied - that is the width - width of these cells has to be increased or decreased to vary the application rate. The discharge rate for a given rotor is controlled by changing the rotor speed that is also possible, but it may damage, damage the granules.

The other metering unit is your rotary metering unit. Belt type metering devices are used to bring the fertilizer granules from the hopper. You can see this is the opening if you raise it more gaps will be there. So, more granules will come if you close it - that gap will control the rate of application. The belt will bring granular materials from the hopper and then at the end it will drop it in a rotary spreader for carrying out broadcasting. The belt could be simple belt or the belt could be a wire - flat wire belt, usually stainless steel that will drag

the material along the hopper bottom and others employ rubberized fabric belt, that the belt could be rubber belts. And the discharge rate as I said you can control by adjusting the gate above the belt and it can be split into 2 or more streams. That means, if you want to put 2 or 3 spreaders you can divide it. So, that is also possible.

Then the other positive metering unit is your fluted roll, just like your fluted roller metering mechanism. The fluted metering devices are used for most granular pesticide applicators. They consist of ground driven vaned or fluted rotor above an adjustable discharge opening. That means, just like a hopper at the bottom this unit should be provided. And, hoppers for row crops sometimes have 2 or 4 openings whose outputs can be used separately or combined. That means, you can have a separate hopper or you can have a separate opening. These rotors fit closely in the hopper bottoms and thereby it provides a positive shut-off when the rotor is not turning. Then ideally the discharge rate should be proportional to the rotor speed, but actually you are not getting the same. The discharge rate is not proportional to the rotor speed. A few tests have shown that the discharge is not proportional to the rotor speed. This is due to incomplete filling of the the vanes that means, the spaces between two - between the flutes. So, because of that you may not get a proportionate increase in the flow rate or the discharge rate. This fluted roller devices - metering devices like many other devices produce a cyclic variation, variation in what ? Variation in the uniformity of the application rate.

Then there is a gravity flow metering device. The gravity flow metering devices are very common on drop type broadcasters, because we want that the granule should come and fall by gravity. The metering rate is controlled by adjusting the size of the opening. So, a rotating agitator is required to break the lumps, so that it can move the material across the opening to assist in feeding. Then you have to have a rotating broadcaster, so that will distribute the fertilizer granules which are falling on the plate - falling by gravity. Then gravity metering devices are essentially run by the ground speed that means, the agitator has to take power from the ground wheel.

Then, we have to discuss the distribution devices. It could be rotary spreaders, gravity spreaders, or ram-air spreaders. Now, I am showing you three figures. So, these are all rotary spreaders of different designs: one has forward-curved blades, another is a cone-shaped spinner, and the third has forward-pitched blades. So, if you look at this figure, you can see they can be rotated clockwise or anticlockwise - does not matter. So, a rotary spreader usually consists of a single or double counter-rotating horizontal spinner - that is also possible. Then, the direction of rotation is such that the adjacent sides in the counter-

rotating spinners move the material rearward. If you have two plates, one will rotate in this direction, and the other will rotate in the opposite direction. So, they will throw materials to the rear. The spinner blades may be radial, forward-pitched, or rearward-pitched with respect to the radius. The blades could be straight or curved - that is also possible. The forward-pitched blades give greater carrying distances for free-flowing materials, while rearward-pitched blades unload sticky material. So, depending on our requirement, we have to select. Then, the stream of granular material, which is dropped onto the spinner, is thrown by the action of centrifugal force. For a double spinner, the stream is usually split into two by an inverted V-shaped splitter.

Then, the diffuser for distribution. So, gravity diffusers are made of an inverted V-shaped housing, made up of either plastic or sheet metal, at the bottom of the drop tube. The housing has distribution vanes. You can see these vanes or other parts that take the stream of granular material and distribute it evenly into a wide band. So that it can cover a particular band uniformly. Then, unlike rotary spreaders, the gravity-type diffuser applies chemicals in a more controlled manner and, therefore, is more suitable as an attachment to row crop planters and cultivators.

Then, after distribution, we have to place it. We need a placement device. The chemical is applied on the surface or below the surface. With the help of this, we can apply it on the surface or below the surface. Then, the surface applications are often incorporated into the soil by a tillage tool, and if you are applying a tillage tool, it has to be done before planting that is another constraint, you can say.

On growing crops, especially solid-planted crops, the chemical is nearly always applied as top dressing; we cannot utilize any tillage tool there. Fertilizer may be placed below the surface by a planter or a cultivator or placed deep into the soil using a chisel plow or drill into established pastures and other sods with special equipment. Then, during row crop planting, banded placement is made with applicators that are independent of the seed furrow openers. We have to have two furrow openers. Double disk. What are the furrow openers? We can use a double disk, a single disk, or a runner-type opener similar to seed furrow openers. Then, fertilizer grain drills deliver the fertilizer to the seed tubes, placing it in direct contact with the seeds in the furrows. Direct contact means a little away. You cannot apply it directly on the seed. You can have separate disk openers, and those are provided in front of the seed openers so that the seed row is not disturbed.

So, these are some of the references. And in conclusion, I can say we discussed the need for chemical application, then we classified different granular chemical applicators and their working principles, and also discussed the functional processes which are required for the application of granular chemicals.

Thank you.