

APPLICATION ACCURACY AND DISTRIBUTION UNIFORMITY OF VARIABLE RATE FERTILIZER APPLICATION

A.Behiç TEKİN¹, Kamil Okyay SINDİR²

Abstract: *In recent years, researches in agriculture is mainly focusing on increasing the productivity either by introducing new bio-technological crops or applying lower but more effective production inputs, such as seeds, fertilizers and sprays. In this respect, especially during the last decade, the technology, named as precision farming, has been developed which particularly aims at environment-friendly, sustainable and economical way of crop production.*

Fertilizer application is one of the most important operations in agricultural production. With this new technology of Precision Farming, grid or zone sampling is employed to determine the variability of the farmland soil fertility and fertilizers at variable-rates are applied onto each of these grids or zones.

The popularity of spinner disc fertilizer applicators for granular fertilizer application along with increased interests to using of variable rate application technology has raised concerns about application accuracy and uniformity. The uniformity and accurate application of fertilizer is a major requirement to achieve benefits from variable rate fertilizer application.

In this study, application accuracy and uniformity of variable-rate fertilizer applicators is evaluated and challenges and opportunities of getting best distribution and accuracy for variable rate applicator is discussed.

INTRODUCTION

Because of the economic and environmental problems people in agricultural sector are seeking more competitive methods for producing food. Development of technologies (such as global positioning system, variable rate application equipment and so on) enables farmers to produce food economically and environmentally.

Traditional way of input application in agricultural production is treatments of all areas uniformly without concerning variability in soil and field conditions. Fertilizer application is one of the most important steps in agriculture. Traditional application method of fertilizer is to collect soil cores throughout a field and mix into a composite sample. This sample is then analyzed to determine unique fertilizer recommendation and fertilizer is applied to whole field according to this result. Variability is known by producer but can do almost nothing in order to manage since the technology developed and electronic parts are available at purchasable cost in agriculture. Today, in reality, variability could be measured and used to justification of fertilizer application. This approach is called "Site Specific Crop Management".

Searcy (1995) defined "Site Specific Crop Management" as "using local parameters, to apply production inputs to small areas with the same soil and crop characteristics". Due to the soil type, fertility, slope and other local parameters, spatial variability which affects food production occurs. Therefore, now, due to developed technology there is potential to vary inputs (fertilizer, seed and chemical) as a function of field location.

Smith et al. (1990) has shown that farmers can save using VRT technology. This study reported that one farmer saved approximately \$18.000 on 400 hectares of corn variable rate application over the traditional method. Another farmer has saved more than %50 of his fertilizer cost.

Popularity of using variable rate fertilizer application has increased. There are two method of variable rate fertilizer application; map based that is used widely and

sensor based. Spinner disc granular fertilizer applicator is widely used to apply fertilizer to field. Because of the popularity of this equipment, they are used for variable rate fertilizer application with necessary equipment. But limitations of this technology are unknown and there is some concern about using this technology.

Overview of Variable Rate Fertilizer Applicator

In order to apply inputs according to location and application map tractor-implement combination must have VRT system. The variable rate application technology consists of GPS receiver, controller, radar speed sensor and actuator (Figure 1). GPS determines the location of tractor on farmland via using satellite signals which is spread by 24 satellites orbiting around the world. Controller sends the rates signals to actuator according to loaded application map, the determined location by GPS and actual velocity of tractor- implement measured by Radar speed sensor. The actuator changes the dosage rate.

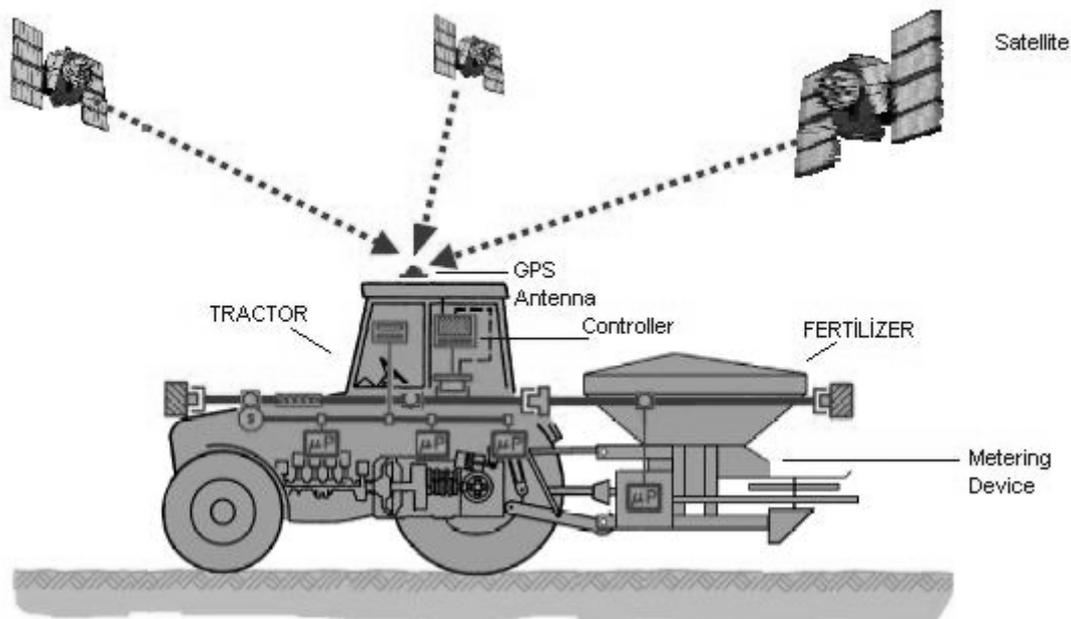


Figure 1- Variable Rate Fertilizer Application

An accurate execution of a fertilizer application map is a major requirement in order to get benefits from variable rate fertilizer application. Application uniformity is also important parameter to assess variable rate application. Fulton (2001) outlined that as with any equipment, the question always arises about the accuracy of nutrient application. The technology and fertilizer design parameters may introduce the false sources. In order to assess and achieve application accuracy and distribution uniformity they should be examined.

Possible Problems Sources

Application accuracy and uniformity are significant property to quantify when assessing variable rate fertilizer application and applicator. Application accuracy means to apply determined fertilizer rate to right location. Application uniformity is to apply this rate to the grid/grids evenly. The coefficient of variation (CV) is used to characterize the quality of spread distribution. Lower CV shows the more uniform distribution patterns. The CV differs from 5% to 10% for spinner spreader patterns.

But this variation may be much higher with landscape irregularities. Parish (1991) found CV's vary 20% to 30% in some cases. Sogaard and Kiekegaard (1994) concluded that CV increase under field conditions.

Application Accuracy

Application accuracy mainly depends on the positional and dosing accuracy. Positional accuracy depends on;

1. The Distance (between GPS receiver's antenna and the center of the spreading cone, that affect the final fertilizer distribution location significantly)
2. GPS receiver limitations (consistent positioning accuracy and inherent time delay required for signal processing to determine a location which presents control system challenges at higher field speed)
3. Tractor speed

Griepentrog and Persson (2001) investigated positional lag for three types of variable rate spreader applicators (disc spreaders equipped with conventional free flow hopper outlet and conveyor belt and pneumatic full width boom spreader). They reported that the positional lag which is a cause for wrong timing in rate changes was significantly influenced by tractor speed and implement working width. Disc spreaders applied fertilizer to early where as the boom spreader was too late. In order to reach good application accuracy control system on tractor must consider the total positional lag.

To achieve acceptable application accuracy control system must adjust the actuator for transitions from current rate to new dose according to distance between GPS antenna and the center of spreading cone and tractor speed. GPS receiver limitations depend on its design parameters and working conditions such as weather condition and quality of correction signals.

Wilson (2000) defined that there are two limitations of GPS for vehicle guidance. First limitation is consistent positioning accuracy in the range of sub-meters for a variety of field conditions, (e.g. presence of buildings, trees or steeply rolling terrain, an interruption in satellite or differential correction signals). The second limitation is the inherent time delay (data latency) required for signal processing to determine a location which is significant at higher speeds (presents control system challenges). With development of the technology these limitations will be overcome.

Dosing accuracy depends on;

1. Machinery design and actuator limitations (response time or controller reaction and other technical parameters)
2. Data transfer speed between electronic devices
3. Fertilizer type

Fulton et al. (2000) concluded that limitations exist on VRT equipment that can create application errors where the actual application rate might differ from desired rate, causing inaccuracy. The design parameters of the spreader and the actuators limitations affect the dosing accuracy.

On the commercially available spinner disc fertilizer applicator, the flow control by actuators and so the rate changes are executed by controlling the gate opening or metering device such as apron chain (conveyor belt). Fulton et al. (1999) concluded that the apron chain (conveyor belt) does not perfectly metering fertilizer continuously. It meters the materials in small clumps. The controlling of outlets opening has some draw-backs. The location and shape of outlet significantly affect the material flows. Değirmencioğlu et al. (1992) studied to model the gravity flow of

granular materials and seeds through orifices in various shapes and areas by dimensional analysis. They used shape and area of orifice, locations of the orifice and material properties. The shape differences which are significantly affect the flow, occur while changing application dosage by decreasing/increasing the area of outlet. And while increasing orifice area the flow is increased rapidly.

Data transfer time is also other important parameters on dosage accuracy. Transitions current rate to the new dosage should be executed in a very short time. The time called response time or delay time is cause of needing for transferring data among the components. Short reaction time leads a few irregularities on dosage accuracy.

Different types of fertilizer have its own physical characteristics such as particle size distribution and volume weight. Metering the different types of fertilizer with same actuator is causing wrong dosage rate. In order to achieve exact dosage adjustment must be changed. Fiala and Oberti (1999) conducted a study which was undertaken to investigate the accuracy of a commercial electronic system for the control of dry fertilizer application rate on a centrifugal spreader. Two electric motors were used as actuators. They are connected to metering gates and control the opening angle of the two outlets. They calculated application rate error for three fertilizers and defined the lack of accuracy in the control system was due to the high moisture content of a part of a material used during the tests.

Application Uniformity

Many parameters affect the uniformity of material distribution with spinner disc fertilizer applicator as shown below;

1. Fertilizer Applicator
2. Fertilizer Type
3. Dosage variability
4. Driver's effect

Spinner Spreaders is known for their no uniformity of material application because of working principles of the spinner discs. They spread the fertilizer according to the so-called centre line spinning principle. And with variable rate equipment, more complexity is introduced with continuously changing application rates (Fulton et al, 2001). Spinning spreaders broadcasts the granular materials theoretically in Gaussian Transverse Distribution spread pattern (Figure 2). But many parameters differ to the transverse distribution pattern. Dosage variability affects the transverse distribution pattern (Figure 3). In order to maintain the application uniformity adjacent passes must be equal. Overlap and under lap cause the heterogeneity of the applications which is due to the driver's errors.

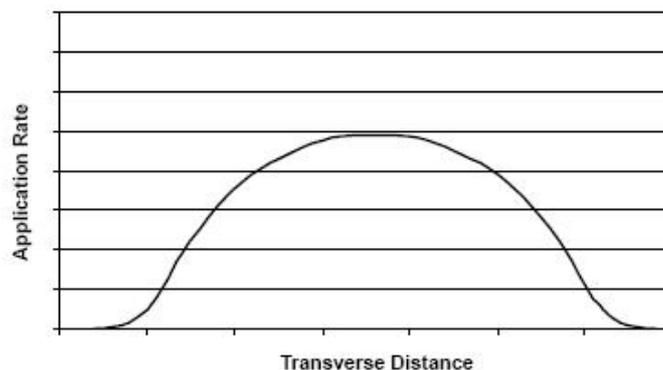


Figure 2- Theoretical Gaussian Spread Pattern.

Different test procedure was developed in order to determine the performance of the spinning disc spreaders such as An ASAE standard (S341.2 Procedure for measuring distribution uniformity and calibrating granular broadcast spreaders) and ISO 5690/1 (ISO, 1981) that introduced a method of assessing the work quality of spreaders with getting of data from these equipment.

Olieslagers et al. (1996) described the fertilizer distribution of a spinning disc applicator. Many parameters, such as orifice position, angular speed of disc, affect the distribution pattern of spinning disc fertilizer applicator. Because of the changing fertilizer flow on spinner disc variable rate application leads to fluctuating spreader pattern that results large deviation from the intended application rates. They (1997) suggested that continuous change to applicator adjustments would be needed to supply uniform distribution pattern when changing rates on the go.

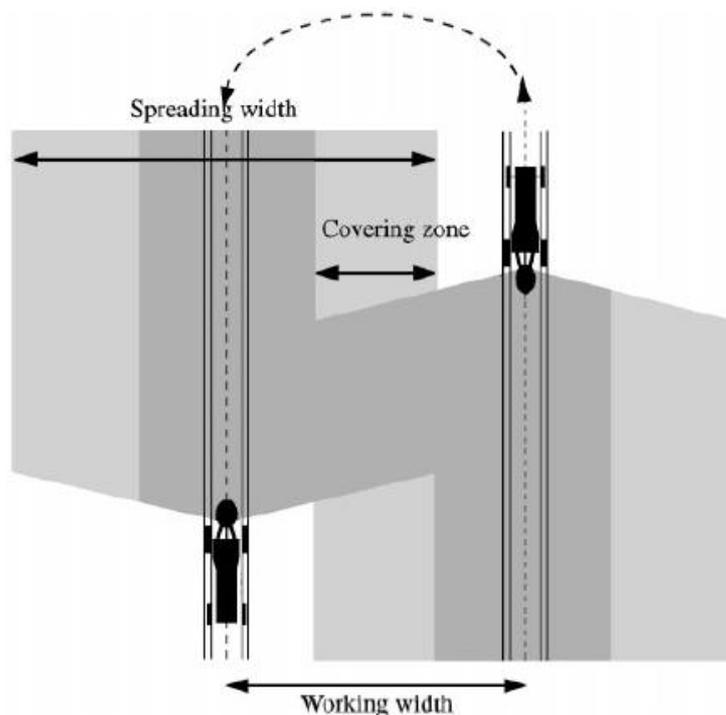


Figure 3- Overlapping in Working With Spinner Disc Fertilizer Applicator

Fulton et al. (2001) investigated the application distribution of a VRT spinner fertilizer spreader. They modified the ASAE S 341.2 standard. Application accuracy was assessed using a matrix of collection pans and following test procedures outlined in this Standard. With performing of uniform and variable rate tests they characterized the application variability of the spreader and tested the effect of rate changes via GPS. And also they modeled uniform and variable rate application from collected data. They concluded average transverse distribution patterns are changed with variable rate dosage (Figure 4). The comparison between the minimum and maximum application rate transverse distribution patterns showed that the spreader adjustment is needed to change in order to maintain uniform pattern.

Fertilizer type is also one of the obstacles in front of the application uniformity that different blended fertilizers have its own chemical and physical properties. Especially physical properties of the fertilizer affect the transverse distribution pattern and so the application uniformity.

S.Tissot et al. (1999) investigated the two different blended fertilizer's transversal distribution patterns after spreading. Several blended fertilizer are difficult

to be spread uniformly by means of a centrifugal distributor. The role of the flow rate and the formulation of the blend is clearly evident.

Griepentrog and Persson (2000) studied variable dosage effect to work quality of disc spreaders. The spread pattern is changed dramatically due to the variable rate dosage.

T.F.Burks et al. (2000) determined the application accuracy with using the navigation aids. Foam makers and parallel tracking device that use GPS and no navigation aids were evaluated. Overlap is a significant element of achieving the desired surface. Light bar guidance system has less variability than other systems. But the mean distance between the parallel passes is much greater than expected. This would be a cause of set-up and operation of light bar system. The results of trucking errors have important effect on distribution pattern.

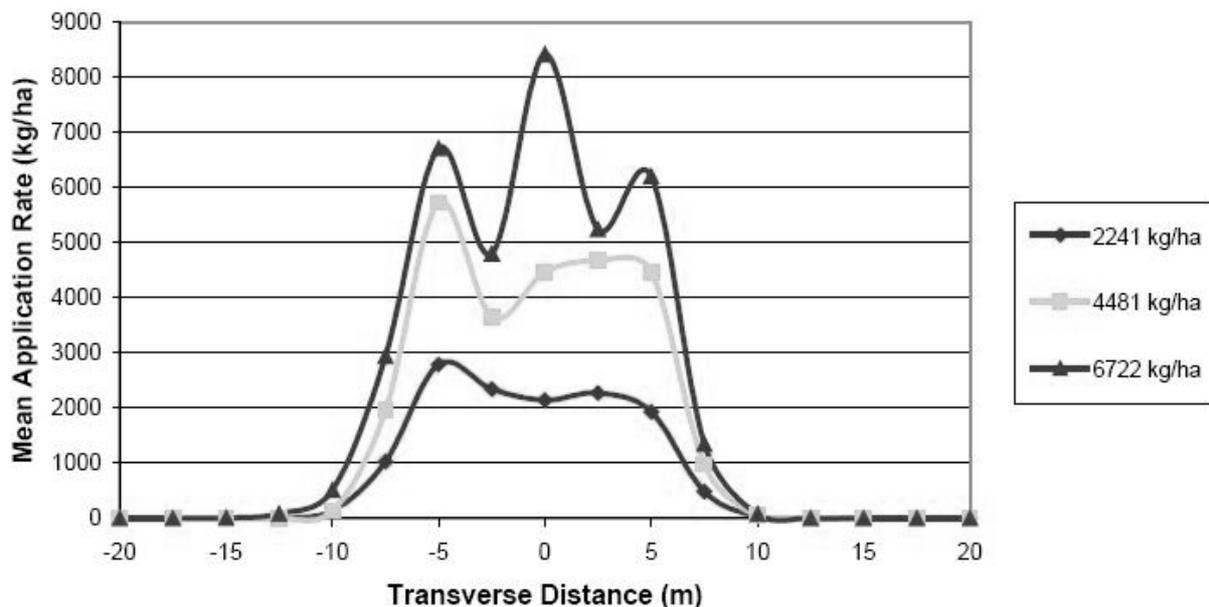


Figure 4- Transverse Spread Pattern in Different Application Rate

CONCLUSION

Fertilizer application is one of the most important steps in agricultural production. Fertilizers play a significant role in production cost and environment. With the new techniques called Variable Rate Application Technology farmers enable to apply according to variations in plant nutrients and accelerate the crop production efficiency and reduce the negative impact on environment. Beside mechanically simple and low cost spinner disc fertilizer applicators are widely used in crop production. Along with these advantages centrifugal spreaders used for granular material application involve complex physics that can not be characterized easily. And now with new variable rate application technology more complexity is introduced due to rate changes.

Many parameters such as VRT Devices, working principle of the fertilizer applicator and driver's errors that affect the application accuracy and uniformity of spinner disc fertilizer applicator. Some resources have been conducted with assessment of variable rate fertilizer applicators that are commercially available or developed by Universities. ASAE and ISO standard related with spinner disc fertilizer applicator and new developed techniques such as image processing have been used in order to assess the VRT fertilizer applicators. And also ASAE S341.2 standard modified to use while determining application accuracy of these machines (Fulton,

1999). Whole researches and tests showed that spreaders must be calibrated and continuous change in various spreader adjustments are needed to maintain uniform distribution.

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ABOUT THE AUTORS

1: Res.Asst., Ege University, Faculty of Agriculture, Dept.of Agricultural Machinery, Izmir, Turkey, E-mail: btekin@agr.ege.edu.tr

2: Assoc.Prof.Dr., Ege University, Fac.of Agriculture, Dept.of Agricultural Machinery, Izmir, Turkey, E-mail: kamil@agr.ege.edu.tr