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PERFORMANCE ASSESMENT OF VARIABLE RATE SPINNER DISC FERTILIZER SPREADER – "PreFer"

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Abstract: The objective of this study was to verify systems performance of developed variable rate spinner disc fertilizer applicator (PreFer) which allows applying of granular fertilizer at variable rates in field conditions. Distribution uniformity and accuracy were assessed using a matrix of collection pans and following test procedures outlined in ASAE Standard S341.2. Spread patterns were produced in triangular shape which is favorable in overlapping process. But it was seen that, triangular shapes are differed due to fertilizer types. The performance of system as found by overlapping transverse spread patterns resulted in a CV of 11% with a 10 m working width in calcium ammonium fertilizer application while the CV and working width for composite fertilizer were 20% and 9 m, respectively. It is clear that working width, and so cell width, was limited by spread width of machine and the CV value while applying different types of fertilizer.

Key words*: Precision agriculture, spinner disc fertilizer spreader, variable rate fertilizer application, performance assessment*

INTRODUCTION

In order to increase the productivity and profitability, agriculture-related researches have been focused on introduction of new high–yield and pest-resistant varieties as well

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as finding the best ways to use agricultural inputs more effectively due to the recent focus on environmental concerns since 1990 [8].

Modern agricultural systems, along with preserving the quality of world's environmental sources, must increase the productivity and profitability for farmers. Variability that exists in growing conditions (soil, crop, disease etc.) has to be considered while managing through a new approach called "Precision Agriculture" and its related technologies (GIS, GPS, VRT). Precision Agriculture is an approach for producing food and fiber in a sustainable way by assigning information technologies. Precision agriculture approach has made a deep impact on the world's agriculture, and although the principals of this trend are the same, the tools and machines should be modified, based on the country and also each farm's conditions.

Many studies in the past were conducted to develop prototype variable rate applicators. Some of them focused on applying fertilizer (spinner disc type or pneumatic type). Sensor based or map based variable rate technologies have been under consideration. In sensor based technology, sensors are employed in order to determine the amount of fertilizer requirement for a particular location and then actuators vary the input rate based on the fertilizer need. Map based technology uses digital maps with location data. The map is generated by analyzing the data obtained by soil sampling, yield mapping etc [15].

Spinner disc type spreaders are very popular, due to the fact that they are simple in design; and also that they are require little maintenance while field work capacities are high [5, 12, 14, 7, 9]. Earlier studies on variable rate granular fertilizer application were carried out by Fulton et al. (2001), who modified a granular spreader truck equipped with a commercially available controller and a GPS system.

Fulton *et al.* (2001) tested the performance of the applicator by modifying ASAE S 341.2 standard. Besides this one, they conducted many studies concerning the performance assessment and modeling of variable rate fertilizer applicators.

Cerri *et al.* (2002) designed and built a system for variable rate lime application. The system included a computer to obtain the coordinate information from GPS and to look up prescription map in order to find the exact rate to instant location, and then send signals to step motor to control the fertilizer flow.

Recently, some researchers have focused on electromechanical control system. There are also commercial products in the world market that have such a system. But, there is no similar system on the spreaders produced by national companies. Tekin (2005) completed his PhD. degree with an output of VRT double spinner disc prototype (PreFer). The system (considering country specific conditions) applies granular fertilizer at variable rate by employing rollers. In order to build the VRT spreader they used main components of commercially manufactured spinner disc granular fertilizer spreader. Tekin and Sindir (2013) reported the system with indoor test results.

Akdemir *et al.* (2007) developed a variable rate controller for centrifugal fertilizer spreader. They employed step-motors to control the fertilizer application rate by varying the outlet area of windows at the bottom of the spreader hopper. Step motors were connected to the rate control levers of spreader.

The objective of this study was to verify the field performance of the developed VRT spinner disc fertilizer spreader (PreFer) while applying granular fertilizer at variable rate in field condition.

MATERIAL AND METHODS

In this study, double spinner disc fertilizer spreader equipped with prototyped variable rate control system (PreFer) was tested while applying granular fertilizer in field condition (Fig. 1).

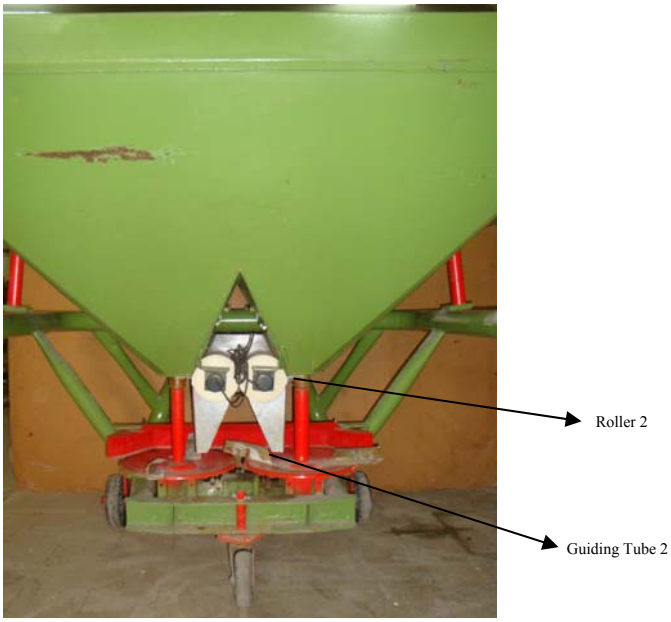

Figure 1. Rollers on spinner disc fertilizer applicator

Transverse distribution uniformity is one of the important indicators for reporting the machine performance. Therefore, in order to quantify the machine spread uniformity, outdoor tests were conducted. Calcium Ammonium Nitrate (26% CAN) and composite 20.20.20 fertilizer were used as test materials.

According to provided collection device dimension, plastic boxes were built (ASAE S341.3). The pans used were 472 mm long, 312 mm wide and 110 mm tall. A carton divider with a 102 mm by 102 mm (50 mm height) grid was also fabricated in order to be placed inside each tray to reduce material from ricocheting out of the pan. Plastic boxes were placed in a line (perpendicular to travel direction) side by side, covering the whole spreading width. In order to allow the tractor to drive over the lines of plastic boxes, the boxes on the wheel track lines were taken. For replication purposes, boxes were placed as three parallel lines (Fig. 2). After each test, the fertilizer collected in each box was bagged, sealed and labelled. Samples were taken to laboratory and weighed. By using the data, transverse distribution uniformities were calculated and the coefficient of variation (CV) was found as an indicator of spread uniformity and was used for evaluating the spread uniformity.

Figure 2. Transverse distribution test site layout

Two different guiding tubes were used to change the fertilizer drop location onto the disc (Fig. 3). During the test process, two different fertilizers were used and the application rates were 250 kg ha^{-1}. All of the tests were conducted when the sustained wind speeds were less than 8.0 km h^{-1} at the height of 1.5 m, and the test side slope was less than 2%. Hopper was filled to approximately 40–50% of the whole capacity when the tests were run. Tests were conducted at 540 rpm (PTO).

(1) (2)

Figure 3. Guiding tubes

During the performance tests of designed variable rate control system, electronic balances (Sartorius BL610, with a range of 610 g and 0.01g precision; Tamtest TTS 2010 with a range of 50 kg, and 20 g precision) were used in weight measurement.

RESULTS AND DISCUSSION

Spreading uniformity of the prototype was examined with different fertilizers and guiding tubes. Initial tests were conducted to reveal the affects of guiding tube on the

spreading uniformity. Although the analysis of transverse spread patterns showed that the effect of guiding tube 1 is similar to that of guiding tube 2, spreading uniformity of guiding tube 1 was less than that of guiding tube 2 (Fig. 4, 5, 6 and 7). Transverse spread patterns of guiding tube 1 was less skewed in shape than that of guiding tube 2. In addition, guiding tube 1 caused fertilizer granules to be collected predominantly in the centre, in contrast to tube 2. Therefore, latter tests were conducted by attaching guiding tube 2 to collect data during transverse spread uniformity tests.

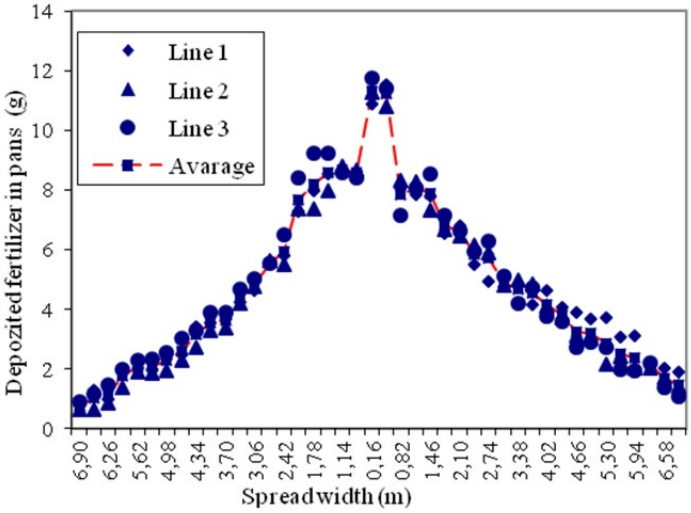

Figure 4. Transverse spread pattern
(Calcium ammonium nitrate- Guiding Tube 1)

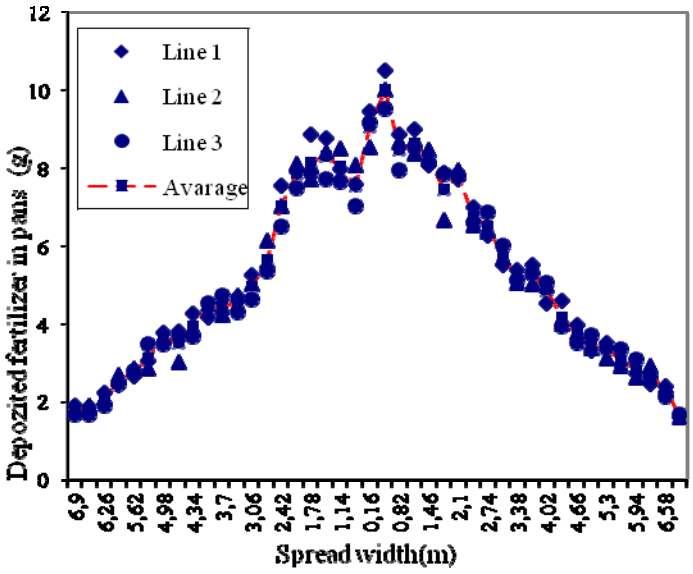

Figure 5. Transverse spread pattern
(Calcium ammonium nitrate- Guiding Tube 2)

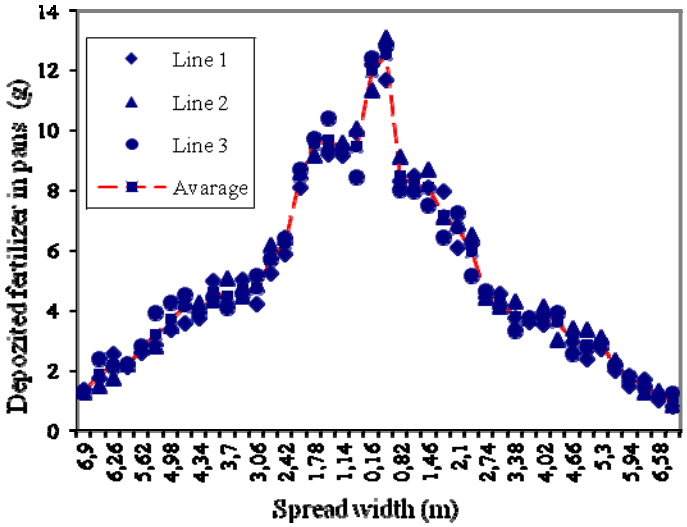

Figure 6. Transverse spread pattern
(Compose Fertilizer- Guiding Tube 1)

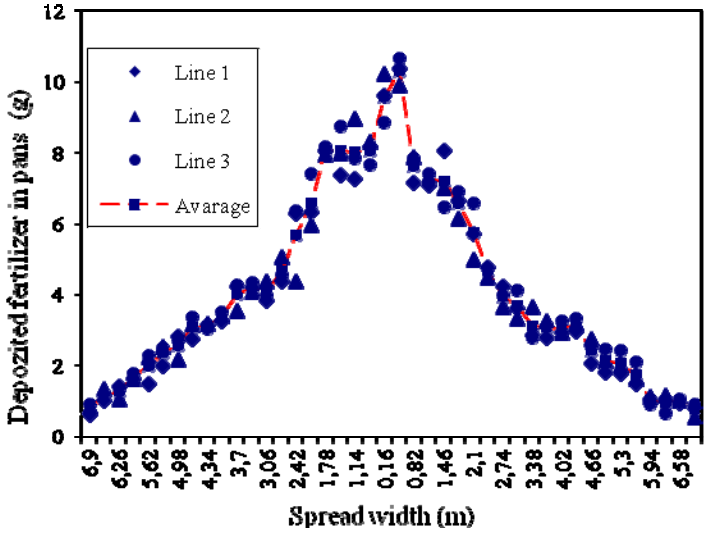

Figure 7. Transverse spread pattern
(Compose Fertilizer- Guiding Tube 2)

Left/right ratio of applied fertilizer was given in Tab. 5. Although the spread patterns of composite fertilizer have some typical irregularities as compared to ammonium, surprisingly, left/right ratios showed that compose fertilizers were applied to both sides of tramline equally.

Table 5. Left/right ratio of applied fertilizer due to guiding tube and type of fertilizer

Left / right ratio (%)	*Calcium ammonium nitrate*	*Compose*
Guiding Tube 1	*0.77*	*0.94*
Guiding Tube 2	*0.79*	*0.91*

Coefficient of variation was used in analyzing of spinner disc spreader performance by scientists [10]. Therefore, the data set also was used in order to determine the relation between the coefficient of variation and the working width (Fig. 8 and 9). Analysis showed that 9 % CV was reached, which corresponds to 9.32 m working width in calcium ammonium nitrate application, whereas CV is relatively higher in compose application with a value of 16% in 8 m working width.

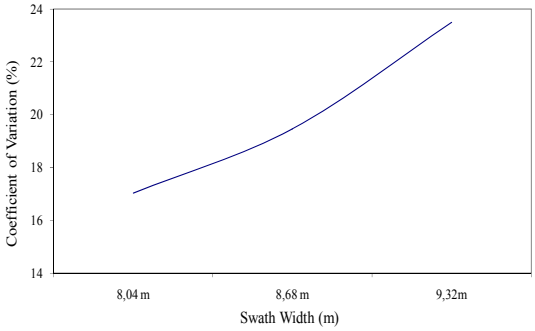

Figure 8. Working width vs CV in calcium ammonium nitrate fertilizer application

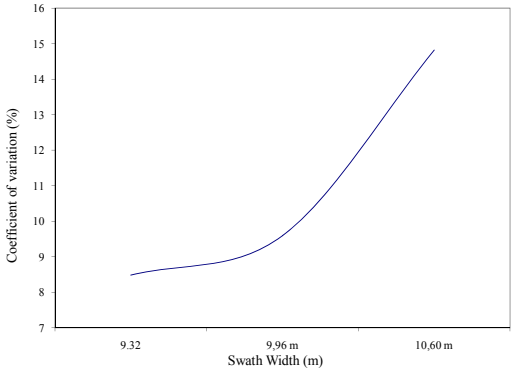

Figure 9. Working width vs CV in compose fertilizer application

Depending on the results concluded from CV versus working width analysis, transverse spread patterns were overlapped by considering basic A–B parallel swathing and in Back-Forth mode since it represents the worst-case scenario and is most popular [12]. The left/right ratio value reached to 0.88 from 0.79 in ammonium application. The ratio also was changed to 1.06 in composite application (Fig. 10 and 11).

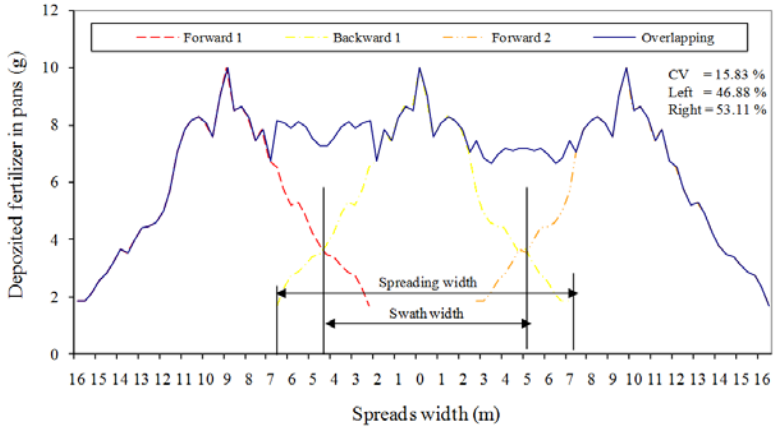

Figure 10. Overlapping in calcium ammonium nitrate (250 kg ha^{-1}) application

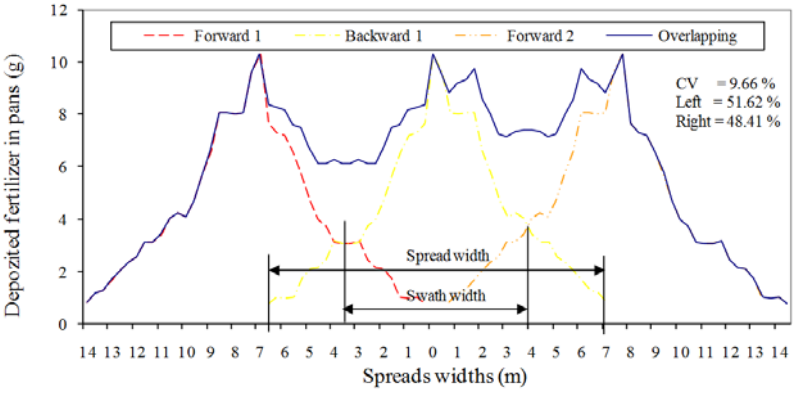

Figure 11. Overlapping in compose fertilizer (250 kg ha-1) application

CONCLUSIONS

A prototype of variable rate fertilizer spreader using a frame of commercially available spinner disc fertilizer spreader was developed considering the country-specific conditions in this study. The machine was mechanically modified and equipped with metering rollers, an electronic control unit, a speed control unit, and a DGPS module.

Initial tests revealed that, dropping point of fertilizer onto disc is affecting spreading uniformity which is coinciding with the results of previous researches. Spreading uniformity tests also made visible the affect of fertilizer type as reported from researches. Experimental tests are required in field conditions to investigate the performance of the system, optimize settings, and to verify if any modifications are required before the system can be used in farm conditions.

Beside this, variation of fertilizer volume realising onto disc is another critical issue since uniformity tests is conducted at fixed rate based on the ASAE S341.3. However, variable rate application brings variation at flow rate which will probably cause distortion on spreading uniformity. Due to the fact that, online adjustments of several parameters such as vane angle, disc speed are needed to overcome the negative effect of flow rate variation. Therefore, further tests and development on the system will be conduct for improving the performance.

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PROCENA PERFORMANSI RASIPAČKOG DISKA PROMENLJIVE NORME RASIPANJA NA RASIPAČU ĐUBRIVA – "PreFer"

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Sažetak: Cilj ove studije bio je da proveri performance sistema razvijenog rasipačkog diska rasipača đubriva sa promenljivom normom aplikacije (PreFer), koji omogućuje primenu granuliranog đubriva u promenljivim normama u poljskim uslovima. Ujednačenost distribucije i tačnost su procenjivane upotrebom matrice sabirnih sudova i po procedurama testiranja koje su istaknute u ASAE standardu S341.2. Modeli rasipanja su izvedeni u trouglastim oblicima što je zastupljeno pri preklapanju. Ali bilo je uočeno da se trouglasti oblici razlikuju zbog tipova đubriva. Performanse sistema koje su uočene preklapanjem podužnih modela rasipanja dao je koeficijent varijacije od 11% na 10 m radnog zahvata sa kalcijum amonijačnim đubrivom dok je su koeficijent varijacije i radni zahvat za kompozitno đubrivo bili 20% i 9 m, redom. Jasno je da je radni zahvat, kao i širina ćelije, bio ograničen radnim zahvatom mašine i vrednošću koeficijenta varijacije pri primeni različitih tipova đubriva.

Ključne reči*: Precizna poljoprivreda, rasipački disk, promenljive norme aplikacije đubriva, procena performansi*

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