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Evaluating of Broadcasting Uniformity of Centrifugal and Oscillating Granular Broadcasters

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Abstract: The uniformity and accuracy of chemical fertilizer and seed broadcasting on field surface are significant parameters of broadcaster performance. Improper and inaccurate broadcasting causes abnormal and nonhomogeneous soil fertility which is against to the purposes of sustainable agriculture. Broadcasters also are used for planting seeds like wheat, barley etc.,soit's appropriate performance effect on crop production. The results of this study help us to analyze broadcaster performance parameters and choose suitable device for best fitting to our purposes. In this research, the uniformity performance of oscillating and centrifugal broadcaster was studied. The research was done using factorial experiment in form of randomized complete block design with three factors and three replications. Three factors were used:1- broadcaster type including oscillating and centrifugal, 2-Material types to be broadcasted including a)urea fertilizer, b)ammonium phosphate fertilizer and c)wheat seed with different mass and density were used and 3- broadcasters gate opening rates(two levels including fully open and semi-open outlet gate). All treatments were applied according to ASAE S341.2, 1999 test code. The EXCEL datasheet was used to provide histogram of broadcasting pattern. The performance parameters used were the uniformity of each broadcaster that was measured by using broadcasting pattern and astatistical index, coefficient of variation. The analysis was done with the 99% level of confidence which showed that oscillating broadcaster had higher broadcasting uniformity than centrifugal broadcaster. Also results showed that increasing the average of particles mass would increase the uniformity of broadcasting. Results indicated that increasing broadcasting rate due to increasing output flow rate of particles, would decrease uniformity of broadcasting.

Keywords: Centrifugal broadcasters, oscillating broadcasting, uniformity of broadcasting

INTRODUCTION

There are a lot of environmental and economical reasons for using more accurate broadcasters as a device of reducing undesirable environmental effects.

As chemical fertilizer was one of the important factors which played significant role in increasing the production per area, nowadays feeding plants using chemical fertilizers is recognized to ensure sufficient production. According to the methodthatin which way fertilizers were applied to the soil, the structural and fertility properties of the soil differbased on broadcaster working principles. The fertilizers may be applied before planting, during soil tillage or the seed bed preparation time, during planting and after germination during the active growth period (Srivastava *et al*., 1993).

Tests showed that the percentage of crop production deduction is nearly related to coefficient variation of broadcasters (Prummel and Datema, 1962).

Reduction of the crop production quantity and quality and undesirable effects on soil are most common results of non-uniformity chemical fertilizers broadcasting (Svensson, 1990). The relation between soil and its physiological effects on plants had not been identified completely yet, but it was estimated that undesirable effects of non-uniform broadcasting would economically lose a large amount of money (Svensson, 1990).

These days, uniform distributing and setting the fertilizer down suitably on the soil, had become increasingly important as the effective factors which cause maximum reaction against minimum cost (Moller, 1987). The factors which affected the performance of broadcasting chemical fertilizers are device type, physical characteristic of chemical fertilizer and climatic condition of farm and operator (Svensson, 1990).

Kepner *et al*. (1972) found that there was an inverse relationship between the flow ability of chemical fertilizer and frictional angle, and uniformity of broadcasting

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chemical fertilizers decreased by increasing the frictional angle. Many different indexes were used to measure the uniformity of broadcasting. For calculating the uniformity of broadcasting, indexes of measuring dispersion were stated by Papatheodossiou (1970), Ruhle (1975) and Bergstrom (1979) such as mean absolute derivation, mean squared and standard deviation, coefficient of variation, aspect ratio, autocorrelation and distribution index which each of them can be used in different situation.

Mean squared deviation and standard deviation:

$$\sigma^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2 \tag{1}$$

Population was used instead of sample in order to provide a statistical prediction (Wonnacott and Wonnacott, 1977). Wonnacott used following formula to calculate population variance:

$$\sigma^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2 \tag{2}$$

$$S = \sqrt{\sigma^2} \tag{3}$$

where, S was the data deviation.

Aspect Ratio:

$$AR_l[\%] = \frac{M_1}{M}\cdot 100$$

$$AR_r[\%] = \frac{M_2}{M}\cdot 100 \tag{4}$$

where, AR_l is the value of aspect rate on the left side of symmetry axis, $AR_r$is the value of aspect rate on the right side of symmetry axis, Mis the total weight of collected seeds, $M_1$is the total weight of collected seeds on the left side of symmetry axis and $M_2$is the total weight of collected seeds on the right side of symmetry axis.

Autocorrelation: Autocorrelation is a function for calculating the oscillation time in oscillating broadcasters. Gustafson *et al*. (1982) suggested using autocorrelation function when the broadcasting frequency was high, so that assessment of data in a short time was impossible:

$$r_{uu}(t) = \frac{1}{N}\sum_{i=1}^{N}u(\tau)u(\tau+t) \tag{5}$$

where, $r_{uu}(t)$is auto correlation, $u(\tau)$ is the value of broadcasting volume at the time of τ,$u(\tau+t)$ was is the value of broadcasting volume at the time of (τ+t) and Nis the number of observations.

Distribution index: Clark and Evans (1954) provided a distribution index which was based on the distance between one selected sample and the nearest neighbor.

In this test samples which were measured, select randomly. Assessed index was obtained by calculating predicted distance average and measured distance to nearest neighbor:

$$R = \frac{\bar{r}_A}{\bar{r}_E} \tag{6}$$

where, R is the index of observations, divergence from the value of random distribution by calculating the distance to the nearest neighbor; r_A is the average of measured distances to the nearest neighbor; r_E is the average of expected distance to the nearest neighbor in complete random distribution.

Uniformity of broadcasting over a wide range of conditions is the basic performance parameter of a broadcaster. This parameter determines the quality of broadcasting. If the broadcasting is proper the quality will improve better. As flow unevenness of fertilizer decreases crop yield and net profit decreases. The most used common method for determining the flow unevenness in the coefficient of variations (Speelman, 1979).

Wilhoit *et al*. (1992) assessed the features of a centrifugal broadcaster in relation to broadcasting organic materials on the farm. They found for bigger materials the uniformity of distribution was higher than the smaller materials.

Sogaard and Kierkegaard (1994) measured the coefficient of variation of broadcasting (15-20%) by using rotating broadcasters with variable rate. In two-plane centrifugal broadcasters, planes rotated otherwise, this cause uniformity to increase.

Pettersen *et al*. (1991) studied centrifugal broadcasters and concluded that broadcasting pattern was changed due to changing the size of broadcasted particles of fertilizers.

Moller (1987), Bergstrom (1979), Nilsson (1975) and Brubach (1973) stated that chemical fertilizers properties were the most significant factor in uniformity of broadcasting. These properties were changed by their combination, production method and carrying method through their storage and transfer period.

Bergstrom (1979) studied granular broadcasters and classified the effective factors on broadcasting granular materials into four groups: the type of chemical fertilizer, the type of broadcaster, operator and other factors (farm and weather). However the total result of broadcasting was indicated by the interaction between mentioned factors.

Parish (1986) and Whitney *et al*. (1987) found that the shape of gathering trays affected the amount of broadcasted particles which reminded in trays during the test.

Follet *et al*. (1981) classified the broadcasting pattern into six different types. The most desirable are the flattop, oval and pyramid patterns because they lend themselves to uniform overlapping of swaths. The most common undesirable patterns are M, W and off side patterns.

In this research, the effect of the mass and bulk density and particle density of broadcasting substances on the performance of broadcasting uniformity of each two broadcasters were investigated and the analysis of its results were important to choose physical characteristic of broadcasting substances. Results helped us to choose the correct broadcaster which is appropriate for different working conditions .Investigating the effects of opening broadcasting gate and subsequently the effects of broadcasting rate variations on the performance of broadcasting uniformity which was done in this research helped us to adjust broadcasters, volumetric seed meter.

Finally the purpose of this study is to make a precise and uniform material broadcasting on farm and avoid to broadcasting extra chemical fertilizer on farming soil, so that decreases undesirable effects of agriculture on environment. In addition consuming less nutritional elements reduces agriculture costs.

MATERIALS AND METHODS

In this research, the uniformity performance of oscillating and centrifugal broadcaster was studied. Three factors were used:

- Broadcaster type including oscillating and centrifugal,
- Material types to be broadcasted including a)urea fertilizer, b)ammonium phosphate fertilizer and c)wheat seed with different mass and density were used and
- Broadcasters gate opening rates(two levels including fully open and semi-open outlet gate).

All treatments were applied according to ASAE S341.2, 1999 test code.

The performance parameters used were the uniformity of each broadcaster that was measured by using broadcasting pattern and a statistical index, coefficient of variation. The analysis was done with the 99% level of confidence.

This research determines the effect of the mass and bulk density and particle density of broadcasting substances on the performance of broadcasting uniformity of each two types of oscillating and centrifugal broadcasters that were investigated. The analysis of its results was important to choose physical characteristic of broadcasting substances. Investigating the effects of broadcasters gate opening and subsequently the effects of broadcasting rate variations on the performance of broadcasting uniformity which was done in this research helped us to adjust broadcasters, volumetric seed meter.

Table 1: The features of centrifugal broadcaster

Tank capacity (kg)	Tank volume (m^3)	Weight (kg)	PTO velocity (rpm)	Broadcasting width (m)	Forward speed (km/h)
300	0.26	80	540	14	4

Table 2: Features of oscillating broadcaster

Model	Tank capacity (kg)	Tank volume (m^3)	PTO velocity (rpm)	Broadcasting width overlap	Empty weight
Ps303	272	0.25	540	20'-46'	80

Experiments plan: This research was done using factorial experiment in form of randomized complete block design with three replicate. Treatment combinations of these experiments were randomly tested to eliminate environmental effects. Two factors were assessed in this research: Broadcaster type including oscillating and centrifugal broadcasters, the mass of broadcasted seeds, so that three seeds including urea fertilizer, ammonium phosphate fertilizer and wheat seed with different mass were used. Two indexes were assessed: the broadcasting pattern of each treatment combination, the statistical index of coefficient of variations for each treatment combination as a standard for measuring the uniformity of broadcasting.

Performing the experiments: All experiments were conducted in research farm of Agriculture College in March 2011, in Ahwaz, Iran.According to ASAE S341.2 (ASAE standards, 1999), experiments were performed at slope of 2% (quite horizontal grounds, in this research). For putting the tractor in a stability state, broadcasting started 30 m before the broad casting trays location and finished 45 m after it. To minimize wind effect on the uniformity of broadcasting, the wind velocity was in a standard range for all experiments. It was sunny at the time of performing experiments and the wind velocity was less than 8 km/h.Tractor that was used for this experiment was John Deer 2040. The features of centrifugal broadcaster and oscillating broadcaster which were used are summarized in Table 1 and 2, respectively.

Collecting trays: Twenty collecting trays were put in a line on the ground for collecting broadcasted particles to construct broadcasting pattern of each broadcaster, performing broadcasting experiments and determining uniformity pattern specify the factors affecting on it. According to ASAE S341.2 (1999), trays were put symmetrical in a row with equal distances to the longitudinal center line of the tractor. The distance between all trays was equal, except for the middle one

Table 3: Features of broadcasted seeds in this research

Broadcasting material	Ammonium phosphate fertilizer	Urea fertilizer	Wheat seed
Average mass of each seed (g)	0.04	0.003	0.04
Particle density (g/cm^3)	1.70	1.29	1.11
Bulk density (g/cm^3)	0.89	0.66	0.78

which was bigger for making tractor wheels movement possible. Broadcasting started 30 m before trays row and continued to 40 m after trays row to put the tractor and the broadcaster in stable state (Clark and Evans, 1954). The average of each granule mass and particle and bulk density for used granules are shown in Table 3.

Assessed indexes: In this research following indexes were assessed about the broadcasting of the broadcasters:

- The uniformity of broadcasting (coefficient of variations)
- Broadcasting pattern

In assessing variable-rate fertilizer applicators the accuracy of application is an important property to quantify (Fulton *et al*., 2001, 2005).The coefficient of variations is typically used to characterize the quality of broadcasting. Lower values of coefficient of variations tend to be indicative of more uniform distribution patterns (Kim *et al*., 2006).

For measuring the uniformity of broadcasting, coefficient of variations-the statistical index- was used (Srivastava *et al*., 1993).

$$sd = \sqrt{\sum (q_i - \bar{q})^2 / \lambda_t - 1} \qquad (7)$$

$$cv = \frac{100sd}{\bar{q}} \qquad (8)$$

$$\bar{q} = \sum q_i / \lambda_t \qquad (9)$$

where, q_i is the amount of seed in ith the tray, λ_t is the number of trays, $\bar{q}$ is the average amount of trays and sd is the standard derivation of collected amount on the tray.

For measuring the broadcasting pattern, the poured seed on each tray was separately measured using a 0.1 gram accurate scale. The tractor was directly moved toward middle trays with the constant speed of 4km/h. The EXCEL datasheet was used to provide histogram of broadcasting pattern.

RESULTS AND DISCUSSION

The coefficient of variations index was used for evaluation and comparison the uniformity of broadcasting. For performing this purpose, first of all, coefficient of variations was calculated by dividing standard deviation of broadcasting into average amount of trays for each treatment combination. For comparing treatment combinations with each other, then variance analysis and average comparison test were performed. In other words, assessed index was the coefficient of variations of broadcasting for each treatment combination. Results obtained from variance analysis of variation coefficient of broad castingare shown in Table 4. The averages of coefficient of variations of seeds used in broadcasting were shown in Table 5. Averages of coefficient of variations in levels of type of broadcasters and broadcasting substance were compared in Table 6.

Table 4: Results obtained from analys is of variance and coefficient of variations of broadcasting

Variations resources	df	SS	MS	F-value
Repetition	2	0.777	0.6522	0.6522
Type of broadcaster (a)	1	974.480	974.480	1642.4521**
Type of substance (b)	2	250.121	125.060	210.7857**
Interaction of (ab)	2	8.521	4.260	7.1805**
Gate state (c)	1	27.562	27.562	46.4556**
Interaction of (ac)	1	0.514	0.541	0.8675
Interaction of (bc)	2	2.582	1.291	2.1757
Interaction of (abc)	2	0.351	0.175	0.2954

**: Significant at level of 1%

Table 5: comparison of the averaged coefficient of variations of seeds used in broadcasting

	Urea fertilizer	Ammonium phosphate fertilizer	Wheat seed
Coefficient of variations	26.02^A	19.58^C	22.42^B

Averages in different capital letters statistically had a significant difference (Dunken1%)

Table 6: Comparison of the averaged coefficient of variations of type of broadcasters and broadcasting substance

	Urea fertilizer	Ammonium phosphate fertilizer	Wheat seed
Oscillating broadcaster	20.13^D	14.8^F	17.47^E
Centrifugal broadcaster	31.9^A	24.35^C	27.37^B

Averages in different capital letters statically had a significant difference (Dunken 1%)

As it could be seen in the Table 4, two types of broadcaster which used in this research had a significant difference of 1% probability. Also it could be seen in Table 5, that the oscillating broadcasters had more broadcasting uniformity, because these two types of broadcasters applied different broadcasting mechanism. The oscillating type broadcast the seeds in consistent amplitude behind the broadcaster and there was no block on the way of broadcasted grains through the whole amplitude. Thus, depending on the mass of grains and their position in the oscillating pipe, grains were randomly broadcasted on the back. But in centrifugal broadcasters, grains were dropped from the outlet gate of hopper on rotating plane and moved along the radial blades to outer direction of the blade. Grains affected by centrifugal force produced by rotation of the blade, tended to be thrown at all directions. But the back part of broadcaster (tractor side) doesn't allow grains to be spread. Thus grains hit the back body of broadcaster and fell down, this means more grain were dropped in the central area of broadcasting width and as we moved far away from the center, less grains were dropped than the central area of broadcasting width. But as it was mentioned before, in oscillating broadcasters there was no block in the way throwing particles through the whole amplitude. The other reason for this was the transferred energy to particles in oscillating broadcasting system. In the oscillating system which was used for this research, if $L_1$is the length of oscillating pipe, the value of applied force on particle change along the amplitude:

$$f = m(L_1 \sin \alpha)\, \omega^2 \tag{10}$$

where, f is centrifugal force applied on each particle, m is particle mass, $L_1$is the distance between oscillating pipe end and center of oscillation amplitude and $\alpha$is the angle between oscillating pipe and center of oscillation amplitude. α and L_1 changed during each moment and the energy of particles at moment they left the pipe could be calculated as follow:

$$E = mL^2(\sin \alpha)\, \omega^2 \tag{11}$$

where L is the length of the oscillating pipe. This equation showed that by increasing the length of the oscillating pipe, the energy of particles would increase. As the length of the oscillating pipe in oscillating broadcasters was higher than the diameter of plane in centrifugal ones, the higher energy of particles was applied in more limited amplitude which caused the uniformity of broadcasting to increase.

Parish (1991) after some researches on rotating broadcaster with variable rate stated that broadcasting accuracy was an important property in assessment of these rotating broadcasters. The coefficient of variation in these broadcasters varied between 10 to 15%, but this value can be doubled based on the farm type and inequality of ground.

The results of simulating oscillating broadcasters showed that increasing the length of oscillating pipe would increase the average of particles outlet speed (Speelman, 1979).

Effects of broadcasted substance type of the uniformity of broadcasting: As it was shown in Table 4; the difference among three broadcasted substances was significant level of probability of 1%.

The difference among these three broadcasted substances, urea fertilizer, ammonium phosphate fertilizer and wheat seed were clearly shown in Table 5. Referring to Table 4, 5 and 6 it could be stated that with the level of confidence of 99% the type of broadcasted substance caused some differences in coefficient of variations of broadcasting.

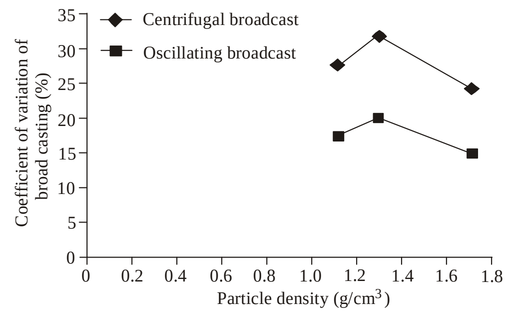

Fig. 1: The effect of particle density on the coefficient of variations of broadcasting

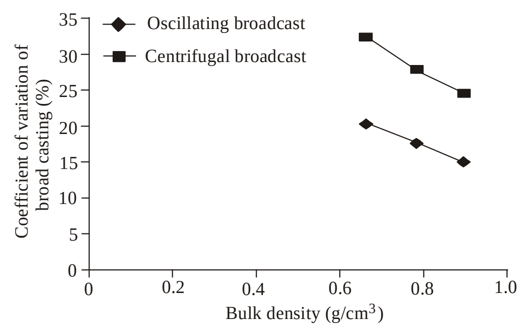

Fig. 2: The effect of bulk density on the coefficient of variations of broadcasting

The average of coefficient of variations of broadcasting for urea fertilizer was higher than the two other broadcasted substances. This was due to the difference in average mass of broadcasting substances. The centrifugal force applied on particles was related to Particle mass:

$$f = mr\omega^2 \tag{12}$$

It meant that by increasing the particle mass the effect of centrifugal force increased and particles were broadcasted in a domain with more uniform distribution. It was also shown in Table 6; that for ammonium phosphate fertilizer the coefficient of variations was less than the coefficient of variations of wheat seed. The reason was the difference in particle density of broadcasted grains. It meant the more particle density of broadcasted substance was, the less air borne drift was applied on and environmental conditions which winding and air resistance were the most important ones, had less effects on the uniformity of broadcasting grains. For each broadcaster the procedure of impressionability of coefficient of variations of broadcasting by particle density is shown in Fig. 1. As it can be seen, increasing particle density would decrease the coefficient of variations of broadcasting which causes a more uniform broadcasting. For each broadcaster, the effect of bulk density on coefficient of variations of broadcasting is shown in Fig. 2. Grain mass average of ammonium phosphate fertilizer and wheat seed were the same and the average was less than grain mass average of urea fertilizer. But the particle densities of these grains were different which caused the coefficient of variations of broadcasting the ammonium phosphate fertilizer to decrease and uniformity to increase.

As it is shown in Fig. 2, the coefficient of variations of broadcasting decreases if the bulk density increases. This highlights the fact that decreasing the bulk density (because of increasing the vacant space between particles) causes less uniform broadcasting.

Speelman (1979) found that increasing broadcasting bulkdensity decreased the coefficient of variation and increased the uniformity of broadcasting in oscillating broadcasters. He also concluded that however in centrifugal broadcasters the difference between particles diameter may cause many variations in the place they fell, in oscillating broadcasters this improved the uniformity of broadcasting.

The broadcaster performance and the uniformity of broadcasting quality depend widely on the physical properties of the fertilizer (Hofstee and Huisman, 1990).

Brubach (1973) found that particle and bulk density of particles affected their broadcasting pattern.

Effects of outlet gate opening value on broadcasting uniformity performance: As it could be seen in the variance analysis of coefficient of variations (Table 4) outlet gate factor,is an important factor which affects the coefficient of variations of broadcasting. Table 4 showed this with the probability of 1% which meant outlet gate opening value affects coefficient of variations of broadcasting with the probability of 99%. The coefficient of variations in different treatments is shown in Fig. 3. As shown in Fig. 3, the maximum coefficient of variations was gained for centrifugal broadcaster in broadcasting Urea fertilizer and the minimum value was obtained in broadcasting Ammonium phosphate fertilizer by an oscillating broadcaster.

As shown in Fig. 3 when the outlet gate was opened more, coefficient of variations of broadcasting increased and the uniformity of broadcasting decreased. This happened because of broadcasted particles effects on each other on the plane in centrifugal broadcasters and in the pipe in oscillating broadcasters.

As the fertilizing rates increase, the values of the coefficient of variations as an indicator of the flow uniformity decrease (Ozsert *et al*., 1988; Turgut *et al*., 1995; Guler, 2005).

Parish (2002) and Yildirim and Kara (2003) found that the uniformity of broadcasting decreased as the flow rate increased.

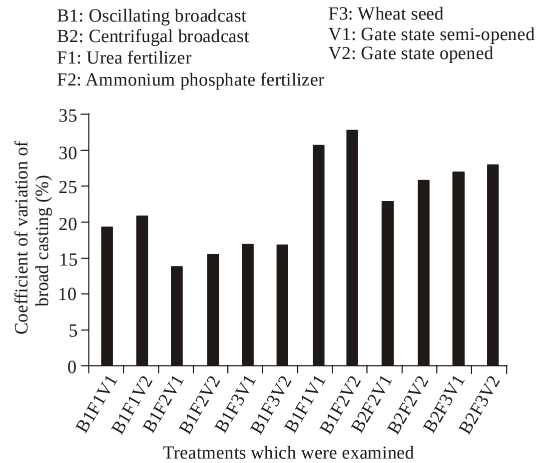

Fig. 3: The effect of different treatments on the average of coefficient of variations of broadcasting

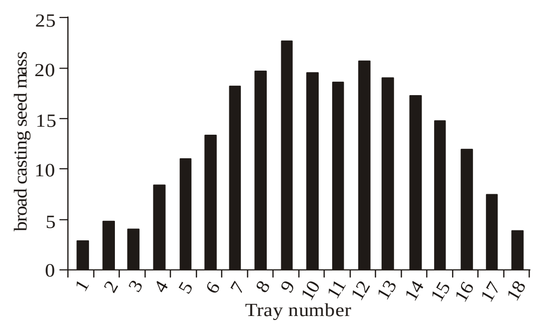

Fig. 4: Histogram of broadcasting pattern of a centrifugal broadcaster for broadcasting super phosphate fertilizer when the gate is opened

Speelman (1979) found that increasing the pipe length in oscillating broadcasters caused energy level of oscillating pipe to increase which resulted in increasing the broadcasting width. He also stated that increasing the broadcasting rate would increase changes in particles transmission speed.

Broadcasting pattern: Broadcasting pattern is important to obtain uniform broadcasting. The broadcasting patterns of two broadcasters were investigated in this study. As shown in Fig. 4 and 5; the broadcasting pattern of centrifugal broadcaster and oscillating broadcaster were pyramidal and humped respectively.

In centrifugal broadcaster, the amounts of broadcasting were higher in the middle of broadcasting width. This could happen due to the mechanism of broadcasting and blocking the front side of the spinning disk by broadcaster.

Srivastava *et al.* (1993) believed that the broadcasting pattern of spinning broadcaster were like one of pyramidal, flattop, oval and humped shapes. He stated

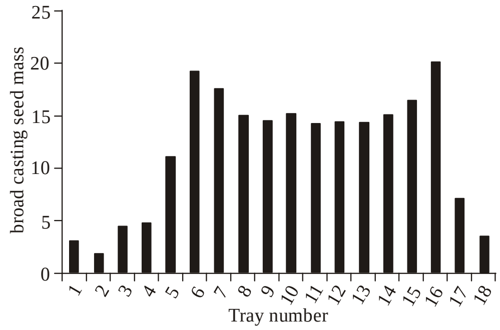

Fig. 5: Histogram of broadcasting pattern of an oscillating broadcaster for broadcasting super phosphate fertilizer when the gate is opened

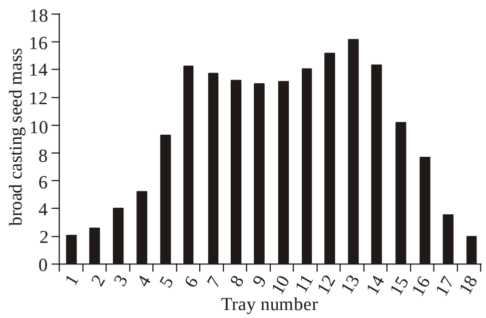

Fig. 6: Histogram of broadcasting pattern of an oscillating broadcaster for broadcasting super phosphate fertilizer when the gate is semi-opened

that pyramidal and flat top pattern with symmetrical and flat sides and suitable overlap caused uniform broadcasting and the possibility of occurring error was higher in pyramidal pattern. Flat top humped and oval pattern led to undesirable uniformity in broadcasting.

In Fig. 6, histogram of broadcasting pattern of an oscillating broadcaster for broadcasting super phosphate fertilizer when the gate is semi-opened. As shown in Fig. 5 and 6, by increasing the flow rate of materials the uniformity of broadcasting pattern tended to decrease.

Parish (2002) reported that the fertilizer flow rate has an important effect on the broadcasting pattern, especially at low rate settings and that there were sight changes at high rate settings.

Olieslagers *et al*. (1996) concluded that broadcasting pattern was changed by some parameters such as the position of outlet gate and the rotary speed of spinning disk. Changing the flow rate of poured materials on spinning disk by variable-rate broadcasters, the uniformity was quite different from the desirable value.

Griepentrog and Persson (2000) studied the effects of variable dosage on the performance of broadcasters. They stated that the broadcasting pattern was changed due to the variable rate.

CONCLUSION

Results obtained from variance analysis related to device type in investigation of uniformity of broadcasting index for centrifugal and oscillating broadcasters showed that uniformity of broadcasting of oscillating broadcasters was more than of centrifugal ones. Oscillating broadcaster required less overlapping in broadcasting pattern to obtain higher level of broadcasting uniformity. This caused broadcasting time to decrease, farming operation to be faster and broadcasting costs to decrease.

Regarding high broadcasting costs in farming operation, following suggestions were offered to improve the performance of broadcasting chemical fertilizers and broadcasting different seeds as well:

- Considering the tests results, it was recommended that centrifugal broadcasters were replaced with oscillating broadcasters, because not only the uniformity of broadcastingof oscillating broadcasters was more than of centrifugal ones but also they were used easily. It could especially be observed at some pauses during the broadcasting operation. The broadcasting of grains was stopped when the power shaft of oscillating broadcaster stopped rotating. But in centrifugal broadcasters, being stopped power shaft didn't stop broadcasting and caused broadcasting substance to be wasted on an area of land.
- It could be obtained from broadcasting rate effects or opening outlet gate that by increasing broadcasting rate, the uniformity of broadcasting decreased. Thus it was recommended that the broadcasting rate reduced by decreasing the value of opening outlet gate to raise the uniformity of broadcasting and speed should have decreased the broadcasting rate was aimed.
- Grains with higher average mass and more particle density led to more uniform broadcasting than lighter grains and increasing bulk density also caused the coefficient of variations to decrease and uniformity to increase. This could be noted for choosing broadcasting substance in farm management.

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