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# EFFECT OF PARTICLE SIZE OF FERTILIZERS ON THE LONGITUDINAL DISTRIBUTION PATTERN OF SOME DELIVERY MECHANISMS

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A b s t r a c t. Physical properties of fertilizers affecting the distribution pattern are of concern to farmers and manufactures of fertilizer, fertilizer distributors and drills. The particle size and the particle size distribution also have a large influence on the fertilizer distribution pattern.

In this study, the effect of the particle size of some granular fertilizers manufactured in Turkey on the longitudinal disribution pattern of some delivery mechanisms in the domestic drills was determined using a scaling-recording system with the aid of PC.

K e y w o r d s: fertilizer distributors, delivery mechanisms, fertilizer distribution pattern

## INTRODUCTION

The importance of the particle size of fertilizers has been appreciated for a long time due to its effect on agronomic response, storage and handling properties, and blending properties. Fertilizers of low water solubility need to have small particle size for rapid dissolution in the soil [1].

Yield losses which must be expected due to uneven fertilizer distribution are determined by crop properties, the type of fertilizer, the amount of fertilizer supplied, the character of the irregularities in the distribution pattern, soil type and climatical circumstances. The yield losses increase as values of the coefficient variation increase. If a value of coefficient of variation, which is bigger than 35 %, is the result of some extremely high over- or underdoses, a relatively large negative effect on crop yields has to be expected. This negative effect increases if the extremes are found at greater distances from each other and if the overor underdoses cover a great area [2].

Crops like oats, which have a relatively less extensive root system in the horizontal plane, are more affected by uneven distribution of fertilizer [2,3].

The desired main properties of a combine drilling machine are an even disribution and the maintaining of the fertilizer rate for a good fertilizing [4,5].

The evenness of distribution of fertilizer is affected by the density of fertilizer, type of delivery mechanism, running speed and flowability of fertilizer which depends shape and size of particle and caking of fertilizer [5,6].

During flow of fertilizer through a fertilizer distributor, continuous discharge at uniform rate from the hopper is essential for proper functioning of the machine. The performance of various farm machines used for distribution of solid chemical fertilizer in the field is greatly dependent on the complex behaviour of the fertilizers [1].

The control of physical properties of fertilizers is not strictly governed by standards,

and the physical condition of a product is mostly the choice of the manufacturer [1].

For uniformity of application, the median value of granule size not less than 1.5 mm and maximum diameter not exceeding 4 mm was recommended [1]. Most researchers determined a lower limit for the particle size. An upper limit is often not given. An upper limit for most fertilizers used in agriculture is a diameter in the range 4-4.75 mm, which is mainly owing to production process. The upper limit of the required particle size depends on the agronomic response [7].

In a study on the longitudinal fertilizer distribution patterns of some delivery mechanisms in combine drilling machines, the most uniform distribution was found for the fluted-wheel delivery mechanism in which the lengths of flutes can be changed. For the delivery mechanism consisted of feeding wheel and adjustable gate opening and the fluted-wheel delivery mechanism in which the lengths of flutes are fixed, the longitudinal distributions were found to be quite uneven at the low fertilizer rates and the low forward speed [8].

## EXPERIMENTAL METHOD

The following fertilizer delivery mechanisms were used in the tests:

- the fertilizer delivery mechanism having the agitator wheels and the adjustable gate opening (DM1; Fig. 1a),
- the fluted-wheel fertilizer delivery mechanism in which the lengths of flutes are unchangable (DM2; Fig. 1b),
- the fluted- wheel fertilizer delivery mechanism in which the lengths of flutes can be changed (DM3; Fig. 1c).

Some properties and sieve fractions of granular triple superhosphate (FT1) and diammonium phoshpate (FT2) used in the study were given in Tables 1 and 2. In the tests, beside the original commerical fertilizers, their three sieve fractions were used:

- particle size 1 (PS1): smaller than 2.36 mm screen size,
- particle size 2 (PS2): between 2.36 and 4.00 mm screen sizes,
- particle size 3 (PS3): larger than 4.00 mm screen size,
- particle size 4 (PS4): the original commerical fertilizers.

The tests were conducted with the aid of a test stand having rolls on which combine drilling machine could be operated at the forward speeds of 1.15 m/s and 2.3 m/s (Fig. 2). The material flowing from fertilizer delivery mechanism was continuously weighed cumulatively by the balance and the data were transmitted to personal computer in continuous stream by the RS-232 C interface circuit of the balance [9]. The balance can automatically weigh in acurracy of 0.01 g and its transfer rates are selectible from 300 to 4 800 bounds.

The scaling-recording time was taken as 1/5 and 1/10 s for the forward speeds of 1.15 m/s and 2.3 m/s respectively in order to weigh the material flowing onto the row of 23 cm [10].The tests were carried out for the same fertilizer rates of 15 kg/da which was adjusted at the forward speed of 1.15 m/s for all the particle sizes. The data determined cumulatively for each replicate were saved in PC. Arranging the data by a programme written in Basic Programming Language, the amounts of the flowing material in each scaling interval were determined in weight.

The values of mean (x), standard deviation (S), and coefficient of variation (CV%) were determined separately with the aid of MINITAB for each replicate. In addition, analysis of variance and LSD test were used to analyse the coefficients of variation and compare the data obtained for the variation sources. Harvard Graphics was used for drawing of graphs.

During the tests the balance was placed just under delivery mechanisms and for each replicate the new sample of fertilizer was used. Fertilizer hopper was filled half and the pressure of the drill tires did not change during tests.

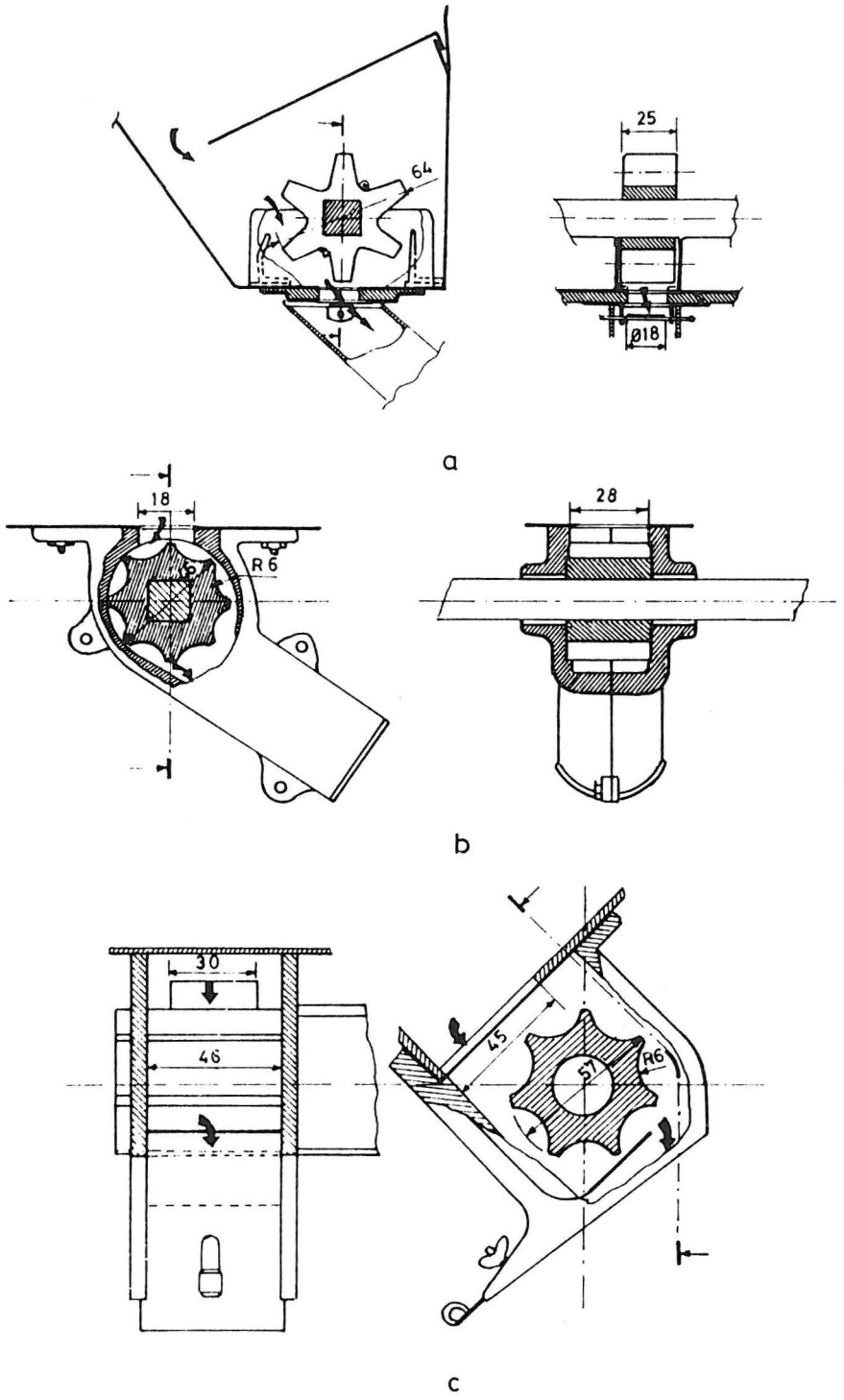


**Fig.1.** Fertilizer delivery mechanisms: a) with agitator wheel and adjustable gate opening; b) fluted-wheel of which effective length is unchangeable; c) fluted-wheel of which effective length is changeable.

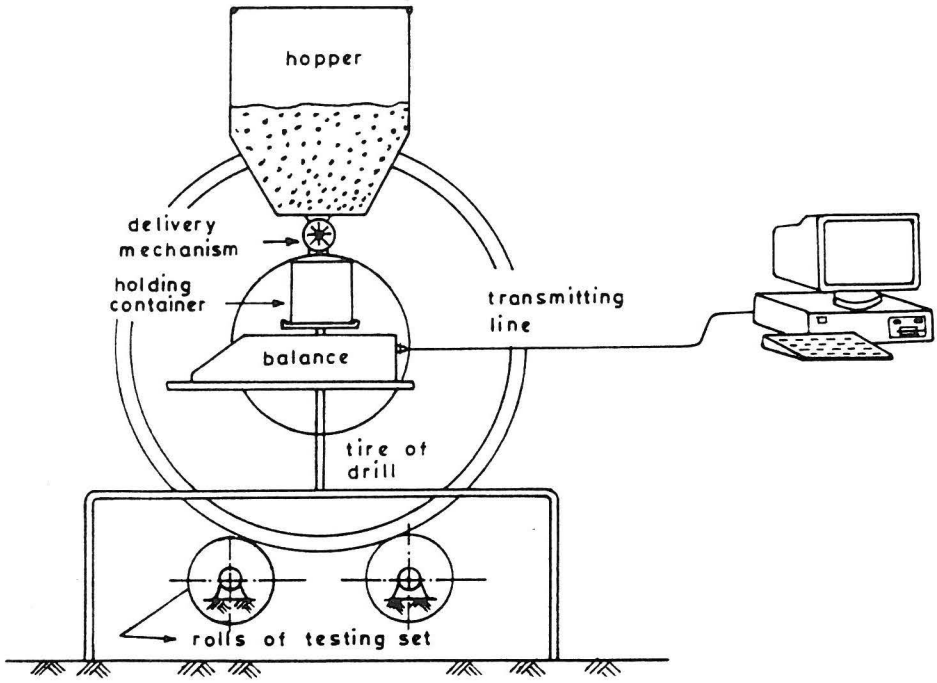


**Fig. 2.** Measurement setup.

**Table 1.** Some properties of the fertilizers used

| Fertilizer type | Bulk density ($kg/m^3$) | Angle of repose (degree) | Moisture content w.b. (%) |
|---|---|---|---|
| Triple superphosphate (FT1) | 980 | 32 | 3.8 |
| Diammonium phosphate (FT2) | 963 | 33 | 5.5 |

**Table 2.** Sieve fractions of the fertilizers used

| Fertilizer type | Sieve fractions (%) | | | | | |
|---|---|---|---|---|---|---|
| | <0.59 | 0.59-1.18 | 1.18-2.36 | 2.36-4.75 | >4.75 | MMD* |
| | (mm) | | | | | |
| Triple superphosphate | 1.8 | 26.0 | 47.7 | 23.9 | 0.6 | 1.97 |
| Diammonium phosphate | 0.1 | 0.5 | 57.8 | 41.5 | 0.1 | 2.10 |

*MMD - Mass median diameter.

## RESULTS AND DISCUSSION

The analysis of variance of the values of CV%, which are determined for each replicate, was given in Table 3 by considering all factors, and LSD test estimates, which are performed to determine the differences among the factors, were given in Table 4.

As can be seen in Tables 3 and 4, the evenness of longitudinal distribution was affected significantly by the delivery mechanism, the type of fertilizer, the particle size

**Table 3.** Analysis of variance of the values obtained from tests

| Source of variation | Degree of freedom | Sum of squares | Mean squares | F value |
|---|---|---|---|---|
| Delivery mechanism (DM) | 2 | 11094.45 | 55447.22 | 213.79* |
| Fertilizer type (FT) | 1 | 402.14 | 402.14 | 15.50** |
| Particle size (PS) | 3 | 1887.07 | 629.02 | 24.24** |
| Forward speed (FS) | 1 | 752.13 | 752.13 | 28.99** |
| Interaction (DM x FT) | 2 | 387.76 | 193.88 | 7.47** |
| Interaction (DM x PS) | 6 | 881.00 | 146.83 | 5.66** |
| Interaction (DM x FS) | 2 | 205.61 | 202.81 | 3.96* |
| Interaction (FT x PS) | 3 | 609.21 | 203.07 | 7.83* |
| Interaction (FT x FS) | 1 | 153.41 | 153.41 | 5.91* |
| Interaction (PS x FS) | 3 | 372.87 | 124.29 | 4.79** |
| Interaction (DM x FT x PS) | 6 | 781.50 | 130.25 | 5.02** |
| Interaction (DM x FT x FS) | 2 | 124.40 | 62.20 | 2.40 |
| Interaction (DM x PS x FS) | 6 | 454.07 | 75.68 | 2.92* |
| Interaction (FT x PS x FS) | 3 | 772.57 | 257.52 | 9.93** |
| Interaction (DM x FT x PS x FS) | 6 | 858.82 | 143.14 | 5.52** |
| Error | 96 | 2490.90 | 25.95 | |
| Total | 143 | 22227.93 | | |

* - Indicates significance at the 5 % level of probability; ** - indicates significance at the 1 % level of probability.

**Table 4.** Comparison of variation sources

| Source of variation | CV% |
|---|---|
| Delivery mechanism 2 (DM2) | 8.48 a* |
| Delivery mechanism 3 (DM3) | 9.52 a |
| Delivery mechanism 1 (DM1) | 27.60 b |
| Fertilizer type 2 (FT2) | 13.53 a |
| Fertilizer type 1 (FT1) | 16.87 b |
| Particle size 1 (PS1) | 10.95 a |
| Particle size 2 (PS2) | 14.02 a b |
| Particle size 4 (PS4) | 14.89 b |
| Particle size 3 (PS3) | 20.94 c |
| Forward speed 2 (FS2) | 12.92 a |
| Forward speed 1 (FS1) | 17.49 b |

* The columns not followed by the same letter are significantly different at the 5% level as judged by LSD test.

and the forward speed ($P<0.01$). The interactions of the factors were significant statistically ($P<0.01$ or $P<0.05$). A good longitudinal distribution was obtained with DM2 and DM3 (CV%<10) while very bad longitudinal distribution was obtained with DM1 (CV%>20). Diammonium phosphate is more proper for delivery mechanisms than triple superphosphate. The fertilizers with small particle size (PS1) has a better longitudinal distribution than the original commercial fertilizer (PS4). The worst longitudinal distribution was obtained with the fertilizers having large particle size (PS3).

In general, a better longitudinal distribution was obtained with the higher forward speed. In order to be able to interprete the variation of CV% values, the variance of the mean values (x), which were obtained at each scaling interval, must be taken into consideration (Fig. 3). Because, another unevenness of distribution, which is caused by over- or underdoses, can affect the values of CV% inversely. This case will be explained at the following paragraphs.

In order to see clearly the performances of the delivery mechanisms and the effect of other factors on these performances, the estimates of variance analysis of individual factors were given in Table 5 and the LSD test estimates were presented in Table 6. In addition, the values of difference between the values of CV% of PS1, PS2, PS3 and those of CV% of original commercial fertilizer (PS4) were plotted in Fig. 4.

From the above tables and figure, the following conclusions can be drawn:

- The evenness of longitudinal distribution was affected significantly by the type of fertilizer and the particle size for DM1, by the forward speed for DM2 and by only the particle size for DM3.
- In general, the fertilizer with smaller particle

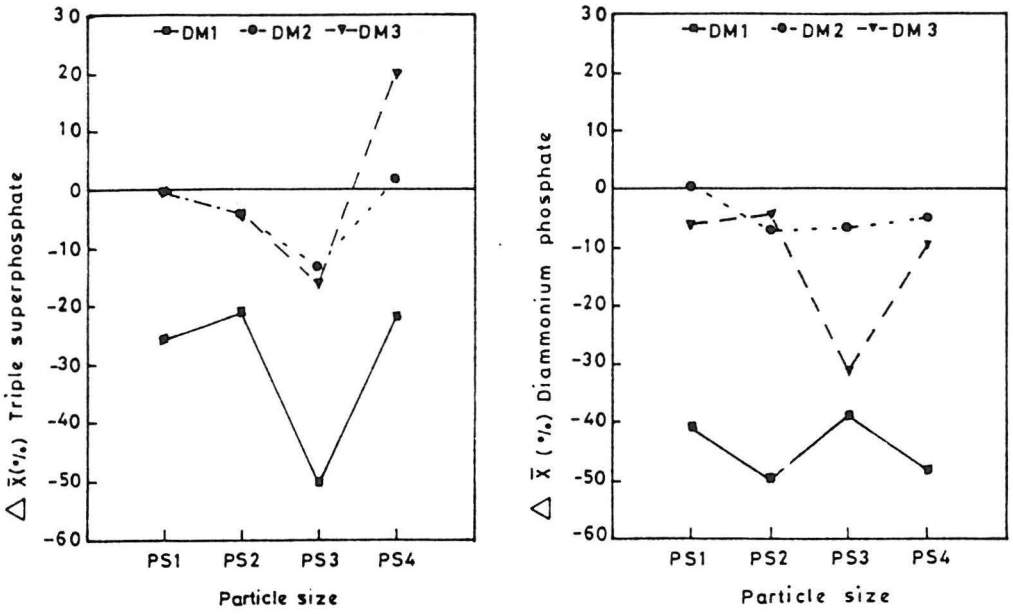


**Fig. 3.** The variation of the fertilizer rate according to the forward speed (scaling interval: 23 cm).

**Table 5.** Analysis of variance estimates for only delivery mechanisms

| Source of variation | Degree of freedom | F value | | |
|---|---|---|---|---|
| | | DM1 | DM2 | DM3 |
| Fertilizer type (FT) | 1 | 12.10** | 0.06 | 4.14 |
| Particle size (PS) | 3 | 9.65** | 2.68 | 21.04** |
| Forward speed (FS) | 1 | 3.63 | 366.28** | 2.44 |
| Interaction (FT x PS) | 3 | 7.49** | 3.14* | 0.64 |
| Interaction (FT x FS) | 1 | 4.39* | 7.02* | 0.16 |
| Interaction (PS x FS) | 3 | 4.43* | 3.18* | 0.33 |
| Interaction (FT x PS x FS) | 3 | 8.56** | 2.80 | 1.68 |
| Error | 32 | | | |
| Total | 47 | | | |

** - Indicates significance at the 1 % level of probability; * - indicates significance at the 5 % level of probability.

**Table 6.** LSD test estimates for only delivery mechanisms

| Source of variation | CV % | | |
|---|---|---|---|
| | DM1 | DM2 | DM3 |
| Fertilizer type (FT) | FT2 23.72 a* | FT1 8.43 | FT2 8.34 |
| | FT1 31.48 b | FT2 8.53 | FT1 10.70 |
| Particle size (PS) | PS1 20.57 a | PS1 7.60 a | PS1 4.69 a |
| | PS2 24.32 ab | PS4 8.39 ab | PS4 7.46 ab |
| | PS4 28.83 bc | PS2 8.91 b | PS2 8.84 b |
| | PS3 36.68 c | PS3 9.04 b | PS3 17.09 c |
| Forward speed (FS) | FS2 25.47 | FS2 4.66 a | FS2 8.61 |
| | FS1 29.72 | FS1 12.31 b | FS1 10.43 |

* - The values which have not the same letter are different significantly at the 5 % level according to LSD test.

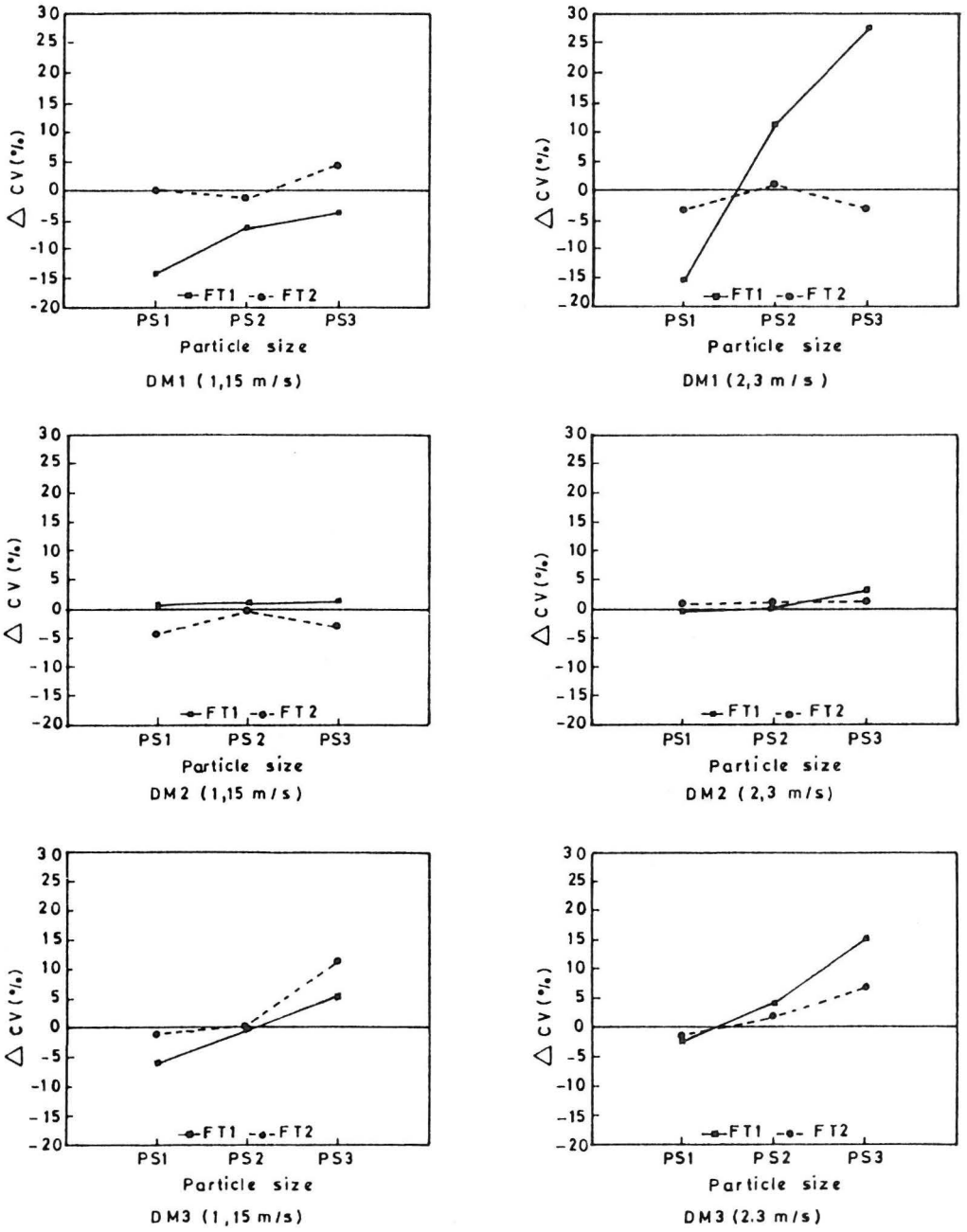


**Fig.4.** Based on the original commercial fertilizer, the variation of CV% in terms of the particle size.

size has a better longitudinal distribution while the fertilizer with larger particle size affect the longitudinal distribution in a negative way. However, the variation of the particle size has a smaller effect on the longitudinal distribution.

- The variation of the forward speed affected the longitudinal distribution positively only for DM2. In addition, the variation of fertilizer rate observed in DM2 was

much smaller than those of others. On the other hand, underdoses were observed in DM1 for all particle sizes, while over- or underdoses were obtained in DM3 for large particle size (PS3) and original commercial fertilizer (PS4).

- Finally, in order to obtain a better longitudinal distribution, some researches on the determination of the optimum size and shape of opening gate for DM1, the proper shaft revolution for DM2 and the optimum flute diameter of flute-wheel of DM3 must be carried out.

## CONCLUSIONS

The evenness of longitudinal distribution was particularly affected by the delivery mechanism, the type of fertilizer and the particle size.

Based on the original commercial fertilizer, the fertilizer with small particle size affected the longitudinal distribution in a positive way, while the fertilizer with large particle size affected the longitudinal distribution in a negative way. For this reason, it can be said that the granular fertilizer must be manufactured in sizes of smaller than 4 mm, and the particles larger than 4 mm must be particularly removed and be subjected to the size reducing process.

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