Journal of Applied Sciences

ISSN 1812-5654

science alert

ANSInet
an open access publisher
http://ansinet.com

Journal of Applied Sciences 6 (14): 2875-2881, 2006
ISSN 1812-5654

Effect of Cone Angle and Revolution Speed of Disc on Fertilizer Distribution Uniformity in Single-Disc Rotary Fertilizer Spreaders

Yildiran Yildirim
Department of Agricultural Machinery, Faculty of Agriculture, Ataturk University, 25240-Erzurum, Turkey

Abstract: The discs used in rotary fertilizer spreaders are flat or cone-shaped. Contrary to flat discs, the cone-shaped discs throw fertilizer with an upward component of velocity and increase the distribution distance. In previous studies, the effect of cone-shaped discs on fertilizer distribution uniformity has not been investigated. In this study, therefore, the effect of the cone angle and the revolution speed of disc on the distribution uniformity were investigated with different flow rates using triple superphosphate. The best distribution uniformity was obtained from the combination between the disc cone angle of 0° and the disc revolution speed of 810 min^{-1} with the orifice diameter of 30 mm. Distribution uniformity became worse as the cone angle of disc increased (0°-flat disc, 10° and 20°) and became better as the revolution speed of disc increased (405, 540 and 810 min^{-1}) with all the diameters of orifices (30, 40 and 50 mm).

Key words: Fertilizer spreader, distribution pattern, distribution uniformity, disc, cone angle, revolution speed

INTRODUCTION

The discs with vanes of rotary fertilizer spreaders throw the fertilizer by the action of centrifugal force. These discs may be flat or cone-shaped. A cone-shaped disc has an angle greater than 0° between its own surface and the horizontal plane, while the angle between the surface of a flat disc and the horizontal plane is 0°. Therefore, the particles discharge from a cone-shaped disc with an upward component of velocity. As this result, the particles are thrown a larger distance (Srivastava *et al*., 1993; Hofstee *et al*., 1999).

The revolution speeds of discs used on the rotary fertilizer spreaders range mostly between 540 min^{-1} and 1000 min^{-1}. Olieslagers *et al*. (1996), using a twin flat disc fertilizer spreader reported that as the revolution speed of disc was increased, the distribution width increased. Aphale *et al*. (2003), using spreader with a flat disc with different material, notified that the mean distribution distances increased with an increase in the revolution speed of disc (from 540 to 810 min^{-1}). Dintwa *et al*. (2004) reported that the revolution speed of disc (280, 516, 752 and 910 min^{-1}) had the effect on fertilizer distribution pattern in single-flat disc spreader. Carman (1991) determined that the distribution uniformity increased as the revolution speed of disc with a cone angle of 2° was increased. But, the effect of different cone angles along with different revolution speeds of disc on fertilizer distribution uniformity is unknown.

The objective of this study was to determine the effect of disc cone angle on fertilizer distribution uniformity and the best combination between the cone angle and the revolution speed with different flow rates for triple superphosphate.

MATERIALS AND METHODS

A domestic mounted single-disc rotary fertilizer spreader mounted on a tractor was used in the experiments. The fertilizer used in the experiments was triple superphosphate. Bulk density, moisture content and repose angle of this fertilizer were 1057 kg m^{-3}, 3.51% and 35.50°, respectively. The sieve analysis and mass median diameter of this fertilizer are shown in Table 1.

The experiments were performed with a flat disc and two conical disc, three revolution speeds of disc and three flow rates of fertilizer. The cone angles of the discs used in the experiments were 0° (flat disc), 10° and 20°. The dimensions of these discs and the angular position of circular orifice with respect to travel direction are shown

Table 1: Some physical properties of triple superphosphate

Sieve fraction	Retained on sieve (%)
<1.6 mm	1.85
1.6-2.00 mm	4.40
2.00-2.80 mm	51.83
2.80-3.35 mm	23.72
3.35-4 mm	15.34
>4 mm	2.85
Mass median diameter (mm)	2.71

Corresponding Author: Yildiran Yildirim, Department of Agricultural Machinery, Faculty of Agriculture, Ataturk University, 25240-Erzurum, Turkey Tel: +904422312550 Fax: +904422360958

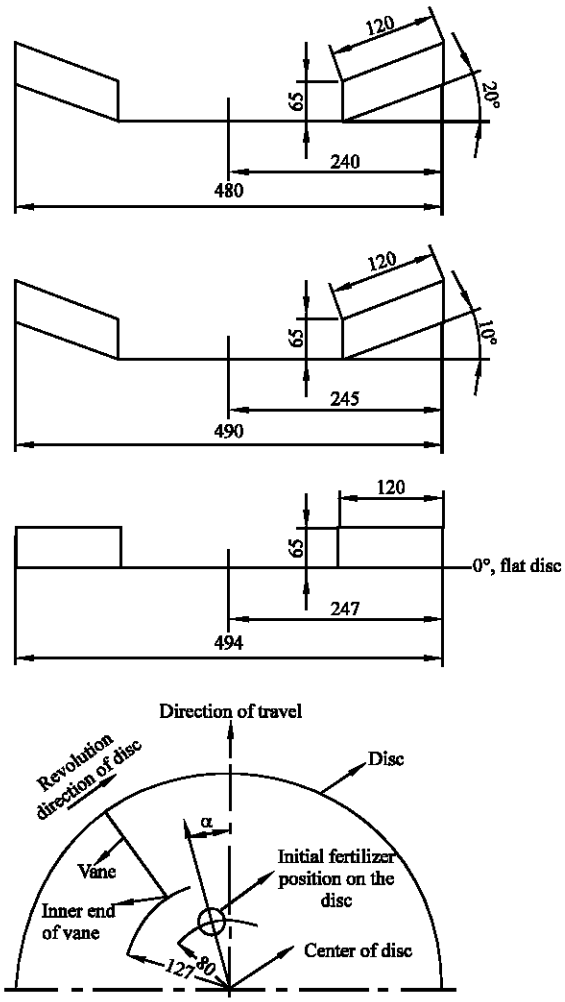

Fig. 1: Dimensions of discs and positions of orifices

in Fig. 1. The discs were run at the revolution speeds of 405, 540 and 810 min^{-1} in the experiments. The height of the discs from the top of the collection trays was 600 mm. The ground speed was 4.44 km h^{-1} in all tests. The experiments were conducted according to ASAE S341.2, Procedure for Measuring Distribution Uniformity and Calibrating Granular Broadcast Spreaders (ASAE Standards, 1998).

The circular orifices with diameters of 30, 40 and 50 mm at the bottom of the conical fertilizer hopper were used for obtaining the different flow rates. The flow rates obtained from these circular orifices with diameters of 30, 40 and 50 mm were 8.85, 22.69 and 43.27 kg min^{-1}, respectively.

The heights and lengths of ⌐ type vanes used in the experiments were 65 mm and 120 mm, respectively. The six of this vane type were mounted radially on each disc. The distance between the center of disc and the inner end of vanes and the average feeding radius of the fertilizer on the disc were 127 and 80 mm, respectively (Fig. 1).

Collection trays were 500 mm wide, 500 mm long and were subdivided into compartments with 10 cm wide, 10 cm long and 10 cm high made of cardboard to decrease the possibility of particles ricocheting out of trays.

Collection trays were placed adjacent to each other in a line perpendicular to direction of travel of the spreader. Thus, the swath width of 26 m was obtained. One collection tray on each side of centerline was removed to allow the tractor wheels to pass through the collection trays. The amounts of fertilizer, at the locations removed the collection trays, were interpolated from the adjacent collection trays (Parish, 2003).

The fertilizer collected in each tray was weighted using a precision balance with an accuracy of 0.01 g. The coefficient of variation (CV) of fertilizer weight data were calculated based on the side-by-side circuitous mode of operation, according to ASAE S341.2 (ASAE standards, 1998).

The preliminary tests were conducted to determine the angular positions of the orifices obtaining the optimum pattern performance with flat disc at the revolution speed of 540 min^{-1} for each orifice. According to the preliminary tests, the angle α between the center of orifice and the travel direction for the orifice diameters of 30, 40 and 50 mm were 5°, 10° and 20° counterclockwise, respectively. All experiments were performed with these angular positions.

The treatments were arranged factorially in three replications including three cone angles of disc, three revolution speeds of disc for three flow rates of fertilizer. The analysis of variance (ANOVA) was applied to evaluate the treatment effects for each orifice diameter separately. Duncan's multiple range test procedure was used to compare the mean values of CV obtained from each combination.

RESULTS AND DISCUSSION

Table 2 presents skewing, CV and minimum and maximum values. Skewing value is expressed as the percentage of material on the left side of the pattern centerline compared with the percentage of material on the right side of the pattern centerline. The CV, widely used to characterize the quality of distribution uniformity in overlapped pattern, defined as the standard deviation divided by the mean. The minimum and maximum values are expressed as a percentage of the mean rate in the overlapped pattern. Onal (1995) reported that the difference between amount of fertilizer on left side of the

Table 2: Summary of pattern data[a]

Orifice diameter (mm)	Cone angle × rev. speed	Skewing[b] (%Left/%Right)	CV[c] (%)	Minimum[e] (% of mean)	Maximum[e] (% of mean)
30	0° × 405 min^{-1}	51/49	17d[d]	69	134
	0° × 540 min^{-1}	48/52	12e	80	125
	0° × 810 min^{-1}	47/53	09e	80	114
	10° × 405 min^{-1}	45/55	22c	66	140
	10° × 540 min^{-1}	54/46	17d	74	129
	10° × 810 min^{-1}	53/47	12e	74	123
	20° × 405 min^{-1}	54/46	36a	54	160
	20° × 540 min^{-1}	52/48	26b	56	145
	20° × 810 min^{-1}	58/42	21c	62	130
	LSD		3.340		
	Probability		0.01		
40	0° × 405 min^{-1}	46/54	19d	75	138
	0° × 540 min^{-1}	46/54	15e	76	128
	0° × 810 min^{-1}	49/51	11f	81	123
	10° × 405 min^{-1}	40/60	26bc	66	157
	10° × 540 min^{-1}	51/49	19d	69	138
	10° × 810 min^{-1}	56/44	17de	74	131
	20° × 405 min^{-1}	54/46	40a	50	165
	20° × 540 min^{-1}	56/44	29b	46	149
	20° × 810 min^{-1}	57/43	25c	50	138
	LSD		3.398		
	Probability		0.01		
50	0° × 405 min^{-1}	43/57	23d	72	150
	0° × 540 min^{-1}	47/53	18e	74	131
	0° × 810 min^{-1}	51/49	13f	75	126
	10° × 405 min^{-1}	48/52	30c	60	164
	10° × 540 min^{-1}	52/48	24d	62	148
	10° × 810 min^{-1}	59/41	22d	77	140
	20° × 405 min^{-1}	50/50	43a	50	179
	20° × 540 min^{-1}	51/49	34b	50	153
	20° × 810 min^{-1}	63/37	30c	51	145
	LSD		2.333		
	Probability		0.05		

[a] Each data point shown is the mean of three replications. [b] Skewing in the overlapped pattern is expressed as the percentage of material on the left side of the pattern centerline compared with the percentage of material on the right side of the pattern centerline. [c] The coefficient of variation (CV) is the minimum value (best) in the overlapped pattern. [d] Means followed by the same letter in each group are not significantly different at level of probability specified, according to Duncan's Multiple Range Test. [e] Minimum and maximum points in the overlapped pattern (at effective swath width) are expressed as a percentage of the mean rate

pattern centerline and amount of fertilizer on right side of the pattern centerline (skewing) should be ≤4%. According to Parish (2002), a high skewing value cause a high CV and increase the differences between minimum and maximum values. In an acceptable overlapped pattern, the value of CV should be ≤20%, minimum and maximum values should be ≥80% and ≤120%, respectively (Parish, 2001). Each data point in Table 2 is the mean of each combination between the cone angle of disc and the revolution speed of disc.

The results of ANOVA for each orifice diameter indicated that there were significant differences ($p<0.001$) among both cone angles and revolution speeds of disc. The values of CV from the interaction between the cone angle and the revolution speed of disc were significantly different from each other. These differences were statistically significant at the 1% ($p<0.01$) level of probability for the orifice diameter of 30 and 40 mm and at the 5% ($p<0.05$) level of probability for the orifice diameter of 50 mm (Table 2).

As increased the revolution speed of disc, the values of obtained CV decreased for all the cone angle of disc, therefore the fertilizer distribution uniformity became better (Table 2). For a given the revolution speed of disc, the CV obtained from overlapped pattern increased with increasing cone angle of the disc, which indicated that the uniformity of fertilizer distribution was getting worse. These cases were the same at all orifice diameters (30, 40 and 50 mm).

For all the cases, the values of obtained CV changed from 9 to 43%. The minimum value (best) of CV was obtained at the combination between the cone angle of 0° (flat disc) and the revolution speed of 810 min^{-1} with diameter orifice of 30 mm. The maximum value (worst) of CV was obtained at the combination between the cone angle of 20° and the revolution speed of 405 min^{-1} with diameter orifice of 50 mm.

Table 2 shows, at the same time, the values of CV obtained from the same combination increased with an increase in orifice diameter (therefore increasing flow rate

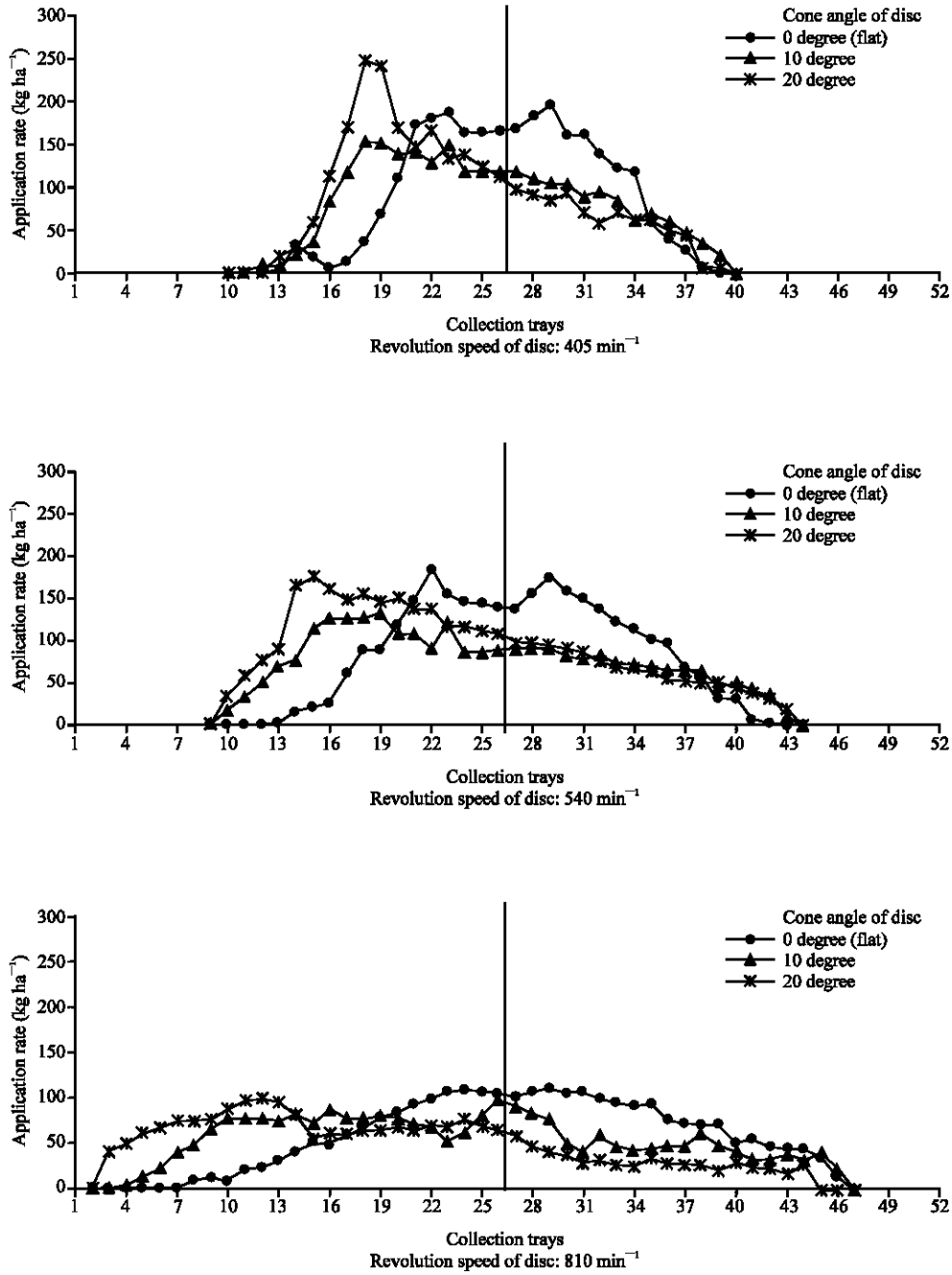

Fig. 2: The distribution patterns belonging to the orifice diameter of 30 mm at the disc revolution speed of 405, 540 and 810 min^{-1}. The center of the disc passed midway between the centers of collection trays 26 and 27. Each line in the graphs is the mean of three replications

onto disc). Parish (2002) and Yildirim and Kara (2003) also reported that the fertilizer distribution uniformity was deteriorated with increasing flow rate onto disc.

All the values of CV obtained at the cone angle of 0° and 10° were found to be <20% for the disc revolution speed of 540 min^{-1}, used generally in practice, except for the combination between the cone angle of 10° and the diameter orifice of 50 mm. For the disc cone angle of 20°, all the values of CV were found to be >20% at all the revolution speed of disc.

Figure 2-4 showed the maximum and minimum points became closer to 100% when the revolution speed of disc

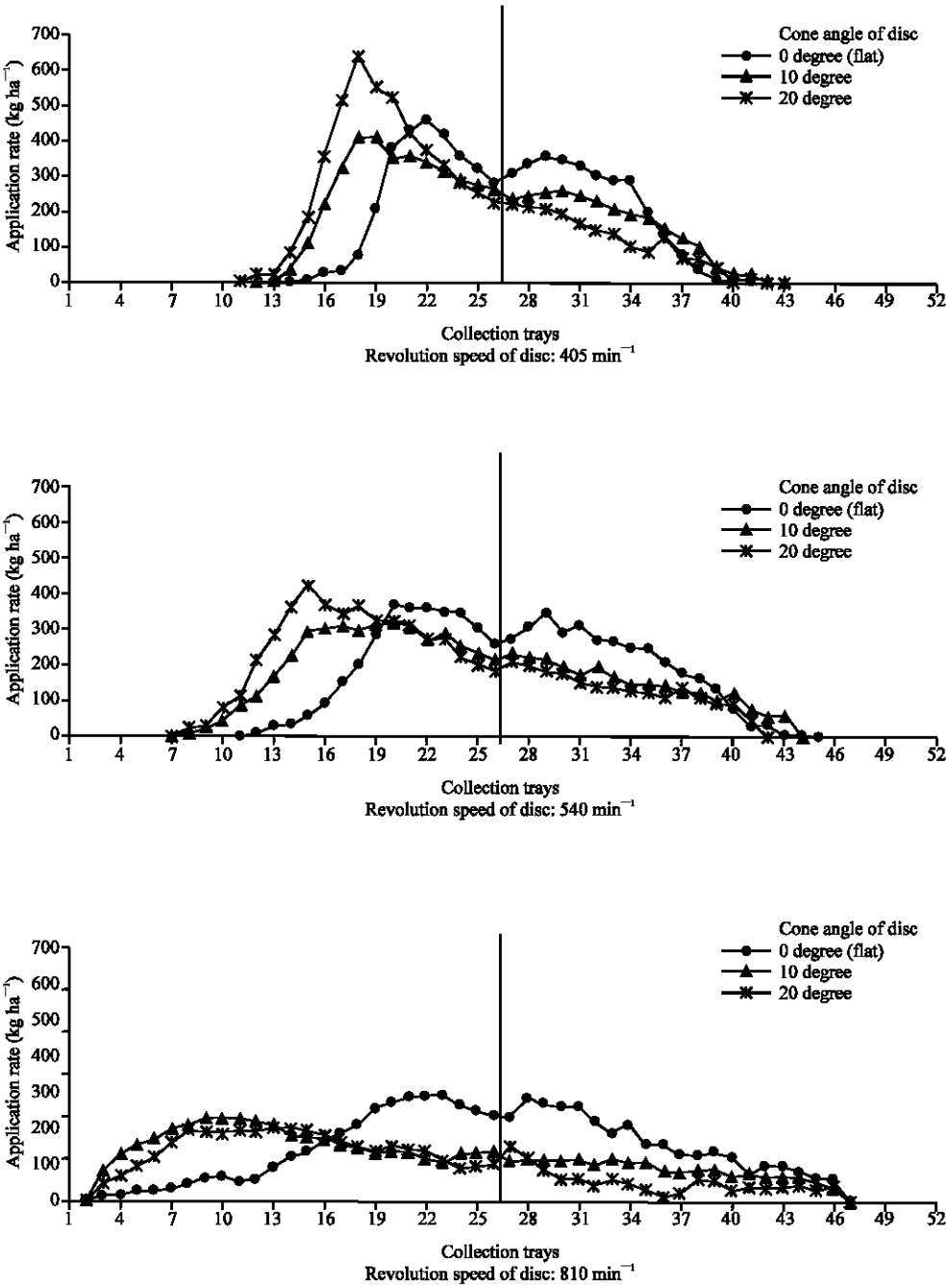

Fig. 3: The distribution patterns belonging to the orifice diameter of 40 mm at the disc revolution speed of 405, 540 and 810 min^{-1}. The center of the disc passed midway between the centers of collection trays 26 and 27. Each line in the graphs is the mean of three replications

was increased (405, 540 and 810 min^{-1}). On the other hand, increasing the cone angle (0°-flat disc, 10° and 20°) caused the patterns to skew more to the left. This case is undesirable for uniformity of fertilizer distribution. According to Grift (2000), an acceptable fertilizer distribution pattern should be similar to the normal distribution (also called Gaussian distribution). As the minimum and maximum values became closer to 100% and the skewing values became closer to 50%, the distribution patterns are similar to normal distribution.

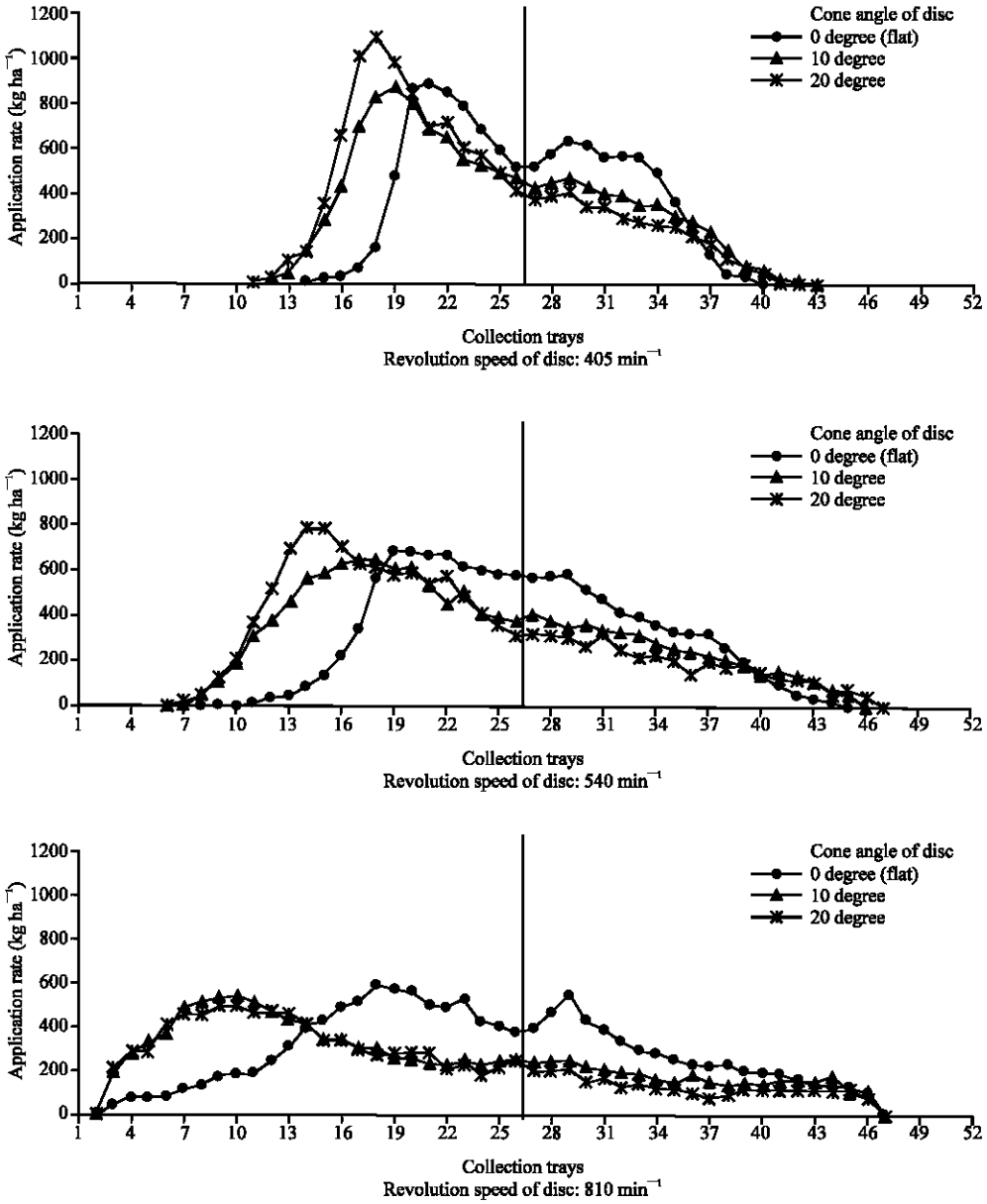

Fig. 4: The distribution patterns belonging to the orifice diameter of 50 mm at the disc revolution speed of 405, 540 and 810 min^{-1}. The center of the disc passed midway between the centers of collection trays 26 and 27. Each line in the graphs is the mean of three replications

CONCLUSIONS

The data from this study demonstrated that the cone angle of disc along with the revolution speed of disc had an effect on the fertilizer distribution uniformity. Increasing the cone angle of disc deteriorated the fertilizer distribution uniformity. On the other hand, as the revolution speed of disc increased, the values of obtained CV decreased. The best distribution uniformity was obtained from the combination between the disc cone angle of 0° (flat disc) and the revolution speed of 810 min^{-1} for all orifices.

The values of CV obtained from all the experiments varied from 9 to 43%. The values of CV for the cone angle of 0° and 10° with the revolution speed of 540 min^{-1} were <20%, except for the combination between the cone angle of 10° and the diameter orifice of 50 mm. Therefore, at disc revolution speed of 540 min^{-1}, used widely in

practice, manufacturers should be taken into consideration that the angle of disc has to be <10° to obtain an acceptable fertilizer distribution uniformity.

REFERENCES

Aphale, A., N. Bolander, J. Park, L. Shaw, J. Svec and C. Wassgren, 2003. Granular fertilizer particle dynamics on and off a spinner spreader. Biosys. Eng., 85: 319-329.

ASAE Standards, 1998. Procedure for measuring distribution uniformity and calibrating granular broadcast spreaders. 45th Edn., St. Joseph, Mich.: ASAE. S341.2.

Carman, K., 1991. Tek diskli gübre dağıtma makinalarında disk çevre hızı ve serbest yarıçapın dağılım desenine etkileri. Selcuk Universitesi Ziraat Fakultesi Dergisi 2: 75-83, Konya, Türkiye [The effect of disc peripheral speed and free radius on the distribution pattern in single spinning-disc type spreader. Selcuk University. J. Agric. Fac., 2: 75-83, Konya, Turkey].

Dintwa, E., E. Tijskens, R. Olieslagers, J. De Baerdemaeker, and H. Ramon, 2004. Calibration of a spinning disc spreader simulation model for accurate site-specific fertilizer application. Biosys. Eng., 88: 49-62.

Grift, T.E., 2000. Spread pattern analysis tool (spat): I. Development and theoretical examples. Trans. ASAE, 43: 1341-1350.

Hofstee, J.W., L. Speelman and B. Scheufler, 1999. Fertilizer Distributors. CIGR Handbook of Agricultural Engineering. Vol. III, Plant Production Engineering. St. Joseph, MI: ASAE., pp: 240-268.

Olieslagers, R., H. Ramon and J. De Baerdemaeker, 1996. Calculation of fertilizer distribution patterns from a spinning disc spreader by means of a simulation model. J. Agric. Eng. Res., 63: 137-152.

Onal, I., 1995. Ekim, Bakım, Gübreleme Makinaları. Ege Üniversitesi Ziraat Fakültesi Yayınları No. 490, Bornova-Izmir, Bölüm 4, S: 481-606.

Parish, R.L., 2001. Pattern uniformity with homeowner rotary spreaders. Applied Eng. Agric., 17: 127-130.

Parish, R.L., 2002. Rate setting effects on fertilizer spreader distribution patterns. Applied Eng. Agric., 18: 301-304.

Parish, R.L., 2003. Evaluation of a homeowner rotary spreader with deflector to close one side of the pattern. Applied Eng. Agric., 19: 641-643.

Srivastava, A.K., C.E. Goering and R.P. Rohrbach, 1993. Chemical application. Engineering Principles of Agricultural Machines. ASAE Textbook Number 6, St. Joseph, Michigan, USA, pp: 265-277.

Yildirim, Y. and M. Kara, 2003. Effect of vane height on distribution uniformity in rotary fertilizer spreaders with different flow rates. Applied Eng. Agric., 19: 19-23.