Agricultura 2002, Vol. 1; 34-39

Impact of various rpm levels on rotary and pendulum spreaders performance

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The paper demonstrates how different levels of shaft revolutions affect the performance of mono-disk rotary and pendulum fertiliser spreaders widely used by Slovenian farmers. Tests have been conducted on a mono-disk rotary spreader manufactured by the Italian company AGREX, and on a pendulum spreader manufactured by the Slovenian company CREINA from Kranj. To establish the impact of different revolution levels on the transverse spread - dispersion, spread width and flow of a fertiliser, both types of spreaders have been submitted to testing at different rpm levels of the tractor drive shaft: at 290 rpm, 410 rpm, and 540 rpm. It has been established that the spread width on both spreaders statistically significant ($P < 0.05$) increases with the increase of the rpm's. The fertilizer flow statistically significant ($P < 0.05$) changes only on the pendulum spreaders, whereas on rotary spreaders it has been found out that the fertilizer flow does not depend on the rpm's. Agricultura 1: 34-39 (2002)

Key words: rotary spreader; pendulum spreader; spread width; spread flow

INTRODUCTION

Fertilisation means adding substances to improve crop productivity (Šestić 1985). Recently, the use of mineral fertilisers has gone up considerably. With regard to the type of the substantial plant nutrients they contain, these fertilisers can be divided into several groups: nitrogen fertilisers, phosphate fertilisers, potassium fertilisers, mixed or compound fertilisers, and microelements used as fertilisers.

There are two types of fertilisation: elementary fertilisation and additional fertilisation (Klobučar et al. 1982).

Mineral fertilisers have been extensively used over the years (Table 1). The fertilisation has been done without any prior soil analysis required for determining the content of individual nutrients in the soil. Such practice proved bad as it affected the soil structure, damaged plants and washed surplus nutrients not utilised by plants into the ground water, which is unacceptable from the ecological and economic point of view.

Beside the N, P, K key components, mineral fertilisers in combination with microelements considerably improve the soil fertility, crop quality and quantity on one hand, and bring negative influence on the other. The nitrogenous component produces toxic nitrates and nitrites, whereas phosphates contain beside phosphorus also toxic cadmium and lead.

We have reached the stage, when the nutrient input must be limited, and fertilisers used cautiously and in appropriate quantities. It is necessary to make soil analyses and prepare fertilisation plans thereby taking into consideration the expected crop and through vegetation utilised nutrients.

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Table 1. Trend in use of nutrients over the last years (Banovec et al. 2000).

	1990	1995	1996	1997	1998	1999
Use (kg/ha)	183	354	360	383	411	392
N (t)	19433	27112	26657	27764	29282	29682
P_2O_5 (t)	9906	15148	14658	13770	15602	16867
K_2O (t)	10359	18277	17586	17283	18610	20508

Fertilisers may be applied manually or by fertiliser spreaders of various types (Novak 1990).

To reasonably use mineral fertilisers, we have to use machines equipped with control and regulation mechanisms for proper application and distribution of fertilisers. Modern mineral fertiliser spreaders feature electronic regulation (Brčić 1981). It is necessary that a fertiliser is accurately distributed in both transverse and longitudinal directions (directions of forward travel), and that a prescribed dosage is achieved.

Present-day mineral fertiliser spreaders are designed to cover in one pass as large working area as possible. This brings us to a question of the application accuracy (uniform coverage), which has become of vital importance in all European countries with highly developed agriculture. Both prices of mineral fertilisers and losses due to poor crop quality resulting from application inaccuracy, and the ecologically objectionable high quantity of nitrates causing ground water pollution dictate as accurate spreaders as possible.

ROTARY SPREADERS

Rotary spreaders apply fertilizers by means of a (quickly) spinning disk with a 50 cm diameter and the circumferential velocity from 12 to 20 m/sec. The disk is fitted with 2 to 5 radial fixed blades. Due to the centrifugal force the rotary spreaders throw the material in a curving fan-type pattern over a distance to the right, front, and to the left (within the range of 120° to 180°), with the swath spread from 3 to 12 m with older models, and from 6 to 18 m with mono-disk spreaders (Jenčič 1982). Twin-disk spreaders may reach the swath spread up to 36 m in one pass. The rotary spreader provides the application pattern not symmetrically behind the machine, and a certain level of skewing is present since the direction of the grain movement deviates from the radial direction (Fulton et al. 2001).

To achieve more uniform distribution and coverage the use of spreaders with two or four disks has become enhanced (Mrhar 1997).

PENDULUM SPREADERS

Instead of a spinning disk, this type of spreaders is equipped with an oscillating tube that throws a fertiliser, which drops through the hopper shutoff. While oscillating, the tube in a way imitates manual spreading of the fertiliser. The swath width with three settings usually ranges from 6 to 15 m. It changes by increasing or decreasing the tube oscillation angle. Nowadays, there are models available that achieve the swath width up to 24 m. Also with the pendulum type of spreaders the centrifugal force principle applies. At each swing the centrifugal force is interrupted and changes the direction of movement.

The result is a more uniform distribution of the fertiliser than with the spreaders furnished with one disk rotating without interruption in one direction only, and throwing in this direction larger quantity of the fertiliser. The metering mechanism operates on the principle that the dosage per hectare depends on the fertiliser flow quantity and driving speed. The flow is proportionally dependent on the shutoff opening below the mixer, which at the same time feeds the fertiliser in order to make the flow more uniform. The oscillation of the tube, generated by the eccentric disk changing the tractor drive shaft rotating into backward-and-forward motion, drives the mixer. The latter does not rotate but oscillates from the left to the right. The fertiliser does not get crushed, which due to too high circumferential velocity of the mixer is not the case with the standard rotary spreaders (Mrhar 1997).

MATERIALS AND METHODS

Spreaders testing

We have tested the mono-disk rotary spreader manufactured by AGREX, and the pendulum spreader of the Slovenian make. Both spreaders were equipped with a 400 l hopper; the pendulum spreader was furnished with the units made by the well-known French company VICON (Krepfl 2001). The spreaders were tested at different RPM levels of the tractor drive shaft (at 290 rpm, 410 rpm and 540 rpm) to establish the impact on the transverse spread - dispersion, spread width and flow of the fertiliser. For this purpose we have used 3 m long and 1,1 m wide Eternit corrugated plates, which were laid one beside the other, with corrugations marked from 0 to 40 (the corrugation number increasing with the distance).

As the test was performed with the tractor in motion, the plates were placed in a way, which allows that the left tractor wheel was driving very close to the first plate, and that the fertiliser was applied to the left. Since the driving at the edge of the plates could be repeated at the same speed, only the levels of the shaft rpm changed. We have chosen the travelling speed of 1 km/h to allow as much fertiliser as possible to drop on the plates.

Both spreaders operated at the medium setting (about half open). The flow of the rotary spreader was set to 5 of 10 possible settings (0 - 10), with the bolt screwed to a desired mark ensuring always the same setting (opening) and preventing the shutoff lever to be too open.

The flow of the pendulum spreader was set to 24. Other possible settings are 12, 18, 24, 30, 36, 42, 48, 54, and 60. The gate opening system related with flow settings prevents the opening to be wider as wished for, as the lever is always pushed up to the end (van Bergeijk et al. 2001).

Rotary spreader testing

To perform the testing we have used the AGREX model XA 400 with one disk featuring 4 blades with variable angles (5 possible settings). The position 3 was chosen. The bottom of the hopper is fitted a mixer and the shutoff featuring two openings (Parish 2001). The material can be applied either only to the left or only to the right depending on the openings chosen. The rpm levels and the direction of the blender rotation are always that of the impeller-type disk. The spreader weighed 50 kg and the 24 kW tractor was required to start the spreader.

Rotary spreader transverse spread - dispersion measurement

To establish transverse spread - dispersion of the rotary spreader, we have used Eternit corrugated plates (300 x 110 cm) laid one beside the other in a way that only application pattern to the left was possible.

To establish the spreading performance, the tractor at a constant speed of 1 km/h and at certain PTO revolutions passed the plates. The fertiliser that dropped on the plates gathered in the corrugations. When the tractor was far enough that the fertiliser no longer dropped on the plates, it stopped and the drive shaft was disconnected (Hofstee 1995a).

The procedure was repeated three times, at 290 rpm, at 410 rpm, and at 540 rpm, with the spreader disk 45 cm above the ground. The test was performed with KAN 27 % N small-grained mineral fertiliser, manufactured by Petrokemija Kutina. Each time the test was repeated, the fertiliser was swept from the corrugations, and each pattern from a single corrugation was weighed on an accurate scale onto the gram exactly. The corrugations were marked from 0 to 40, the corrugation 0 being at the tractor wheel. The testing was performed in a covered warehouse to exclude any influence of wind.

Rotary spreader spread width measurement

A measuring tape was used to measure the spread width during the operation of the tractor standing still. Two men, one at each end, supervised the procedure, which was repeated three times at different shaft rpm levels. With the performed measurement the maximum spread width was established.

Rotary spreader flow measurement

The measurement was taken with the spreader covered from all sides with plastic wrap. The tractor was set at certain rpm levels, the shutoff lever was opened, and the stopwatch activated. After two minutes we closed the shutoff. The fertilizer collected in the wrap was put in a vessel and weighed (Grift 2001).

We repeated the procedure three times always adjusting the spreader to the setting 5. The spreader fitted with an attachment screw to determine the setting (0 - 10), allowed us to always select the same setting.

The hopper contained 50 kg of the fertiliser. After each repetition, the weighed fertiliser was put back to the hopper so as to obtain each time the starting 50 kg.

PENDULUM SPREADER TESTING

To perform the testing we have used the CREINA product featuring a hopper made of synthetic material with the capacity of 400 l. The spreading mechanism made by VICON features three angle settings: 76˚, 96˚, and 112˚. We have chosen the angle of 76˚.

A 35 kW tractor drove the spreader. At the bottom of the hopper there is the shutoff with three openings, which allow the material to flow. During the operation the mixer does not make the full circle but only oscillates from the left to the right.

Adjusting the fertiliser flow is done by means of a setting screw spindle opened to the set position with a shutoff lever (Hofstee 1995b).

Pendulum spreader transverse spread - dispersion measurement

To establish the transverse spread - dispersion we used the same procedure as when establishing the transverse spread - dispersion of the rotary spreader.

The spreader was set to the same height, with the tube 45 cm above the ground, the flow set to 24, the travelling speed of the tractor at 1 km/h, and with different tractor drive shaft rpm levels. The procedure was repeated three times: at 290 rpm, at 410 rpm, and at 540 rpm. Again the tractor started driving before the plates, the spreader open to allow the fertiliser dropped normally only to the left. When the tractor was far enough that the fertiliser no longer dropped on the plates, we stopped the tractor and the material application. Each repetition was performed under the same conditions.

Pendulum spreader spread width measurement

The spread width was measured by using exactly the same procedure as with the rotary spreader: with a measuring tape during the operation of the tractor standing still. The procedure was repeated three times, each time at different shaft rpm levels.

Pendulum spreader flow measurement

We have used the same procedure as with the rotary spreader. The spreader, set to the fixed flow, and with the spindle set to the position 24, was covered from all sides with a plastic wrap. When the tractor was set at certain rpm levels, we opened the shutoff lever and activated the stopwatch. After two minutes we closed the shutoff, and disconnected the drive shaft. The fertiliser collected in the wrap was put in a vessel and weighed.

We repeated the procedure three times, each time at different rpm levels. We filled the hopper with 50 kg of the fertiliser. After each repetition, the weighed fertiliser was put back to the hopper so as to obtain each time the starting 50 kg.

Statistical analysis

Data are presented as mean ± standard deviation and analyzed as follows. Effect of rpm's levels on spread width and flow of fertiliser as well as two different spreaders were analyzed using ANOVA. When a significant F ratio was established, differences were tested by using Duncan post-hoc test. Statistically significant differences were considered at $P < 0.05$.

RESULTS AND DISCUSSION

The aim of the testing was to find out how different shaft rpm levels would influence the machine performance. We have used two machines widely used by our farmers: a mono-disk rotary spreader, and a tractor-portable pendulum spreader. Both spreaders feature factory setting of the shaft rpm levels at 540. We wanted to find out whether the performance of the machines would be affected at lower rpm levels. To ensure the same conditions throughout the testing, the testing was performed on an even concrete surface of a large covered warehouse. The tractor used was fitted with a shaft revolution counter. The latter showed the revolutions at a particular moment, which allowed us to ensure the exact number of revolutions during each repetition.

Fertilizer spread width at different rpm's considerably differ on the rotary as well as pendulum spreaders (Table 2). It can be concluded that the rpm's can affect the spread width. With the increase of the rpm's the spread width increases (Fig. 1). On the rotary spreaders the fertilizer flow does not differ considerably of the rpm's are changed, whereas on the pendulum spreaders the fertilizer flow at 290 rpm statistically differs from flows at 410 rpm and 540 rpm (Table 3). The flow at 410 rpm and 540 rpm on these spreaders does not differ statistically. Consequently, it is not important for the flow on the rotary spreaders at what rpm's the fertilizer is spread. On the pendulum spreaders at low rpm's smaller fertilizer flow is obtained than in case of higher rpm's.

Table 2. Rotary spreader width and pendulum spreader width obtained at different rpm's*.

	290 rpm	410 rpm	540 rpm
Rotary spreader width (m)	13.10 ± 1.00[a]	14.53 ± 0.12[b]	15.33 ± 0.06[c]
Pendulum spreader width (m)	7.43 ± 0.05[a]	11.10 ± 0.10[b]	14.50 ± 0.10[c]

[a, b, c] values indicated with different letters are statistically significant different *(P < 0.05)*
* values are means ± standard deviations

Table 3. Rotary spreader flow and pendulum spreader flow obtained at different rpm's*.

	290 rpm	410 rpm	540 rpm
Rotary spreader flow (kg)	21.41 ± 1.00[a]	21.63 ± 0.12[a]	23.66 ± 0.06[a]
Pendulum spreader flow (kg)	40.85 ± 0.05[a]	45.53 ± 0.10[b]	46.75 ± 0.10[b]

[a, b] values indicated with different letters are statistically significant different *(P < 0.05)*
* values are means ± standard deviations

The pendulum spreaders are so designed that they are adapted to uniform fertilizer dispersion per surface unit and, therefore, the deviations, depending on the rpm's, occur. The results show that the deviations are smaller on the pendulum spreaders, and that, therefore, they are for technical reasons more adequate for fertilizer spreading.

Rotary Spreader

When examining the machine, we first established that its design has become obsolete. A mono-disk spreader is a very old model, yet easy to use and maintain. The gear wheel, protected and placed in a housing, is permanently greased and does not require any special maintenance. The disk is fitted with 4 blades with variable angles (5 possible settings). At the bottom of the hopper there is a standard type shutoff featured with two openings. With the spreader setting about half open (using only one opening), which is done by displacing a connecting rod with a lever, only unilateral spreading, left or right, is possible. This, however, was not included in the test.

The machine metal parts require a lot of cleaning to avoid the problem of rusting of the parts of which the protection layer has been damaged.

The trial spreading showed a strong distribution of the mineral fertiliser in all directions. When conducting a transverse test, the spread pattern was uneven and more fertiliser was applied towards the center and less at the edges.

The calculation of the mean weight of the mineral fertiliser in the corrugations of the working area (that is smaller than the spread width), and the comparison of this weight to the weight of the fertiliser found in the corrugations, indicate as follows: at 290 rpm the far edges received much less fertiliser than the center area. The most uniform pattern with the least skewing was achieved at 410 rpm. At 540 rpm the fertiliser was dispersed in a big curve with the fertiliser turning into dust due to the impact power of the blades.

In the center area, there was a major surplus of the fertiliser noted with regard to the mean value (110 %).

When measuring the spread width, we expected the width to increase at higher rpm levels. Although the test confirmed our expectations, it was interesting to find out that the spread width actually only to a smaller extent depends on the change of rpm levels (Fig. 2). At 290 rpm, the spread width was reduced only by 14 % although the revolutions were reduced by 46 % if compared to 540 rpm, and at 410 rpm the spread width was reduced only by 5.2 % although the revolutions were reduced by 24 % if compared to 540 rpm.

The findings of the flow measurement were very similar. At 290 rpm, the flow was reduced by only 9.4 %, and by 8.6 % at 410 rpm. It can therefore be concluded that the flow does not much depend on different rpm levels.

Pendulum Spreader

The design of this type of spreader has improved but requires more complex maintenance. The oscillation mechanism being under constant load needs regular checking and greasing. The mechanism, enabling the tube to oscillate from the left to the right during the machine operation, is submitted to the forces generated by the constant acceleration and deceleration from one extreme position to another. Both the hopper and the tube are made of synthetic material and thus independent of corrosion. After each use the oscillation mechanism and the shutoff must be rinsed and blown out by compressed air to prevent rust formation.

At 290 rpm, the spread width measurement showed rather small dispersion, an uneven pattern with the majority of the material applied in the center (if compared to the mean value) and much less at the outermost edges. At 410 rpm, the spreader had a wider distribution pattern, but the uniform coverage was still not achieved.

The best results were obtained at 540 rpm, i.e. at prescribed revolutions (Fig. 3). There was still a surplus of the material at the center area, which diminished with the dis-

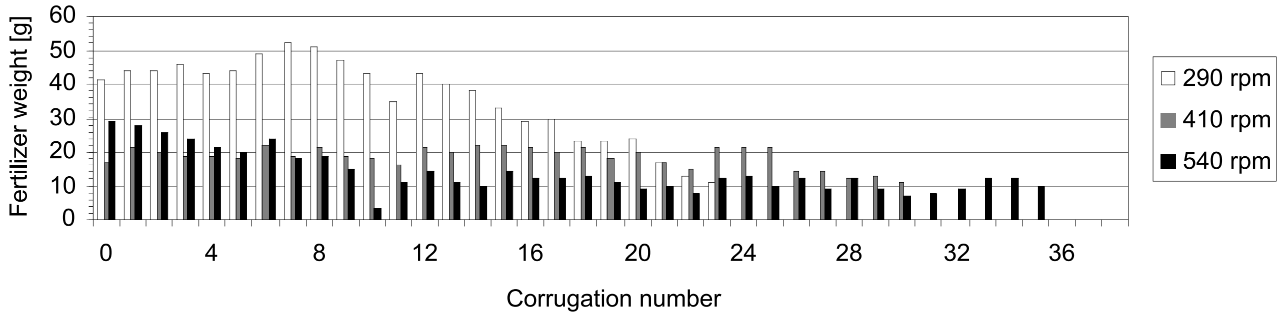

Fig. 1. Rotary spread pattern width at different rpm levels.

tance. The shortage of the material was still noted at the outermost edges.

The dispersion test demonstrated that the spread pattern quality greatly depends on the number of revolutions, and the measurement of the spread width confirmed that. At 290 rpm, the spread width was reduced only by 49 % although the revolutions were reduced by 46 % if compared to 540 rpm, and at 410 rpm the spread width was reduced only by 23 % although the revolutions were reduced by 24 % if compared to 540 rpm (Fig. 4).

As for the flow, the test results obtained showed that at 290 rpm the flow was reduced by 12.8 %, whereas at 410 rpm it was reduced only by 2.6 %.

CONCLUSION

In this article we were dealing with mineral fertiliser spreaders, the area which has become more and more interesting from the viewpoints of economy and ecology. With the aim to reduce to minimum the environmental load and cultivation costs, it is vital to ensure a uniform coverage for which special knowledge and machines are required.

The tests, made on the AGREX mono-disk rotary spreader and CREINA pendulum spreader, have demonstrated the impact of different rpm levels on the performance of the spreaders. To establish the impact, three parameters were chosen: transverse spread, spread width and flow.

The results obtained indicated that different rpm levels had stronger impact on the pendulum spreader. The performance of the pendulum spreader at rated revolutions was better than that of the rotary spreader.

The development of pendulum spreaders along with the technical solutions has increased the fodder production even up to 300 %. In the context of the biomass pedological and nutrient requirements, these spreaders allow additional fertilisation in very small but adequate amounts throughout the

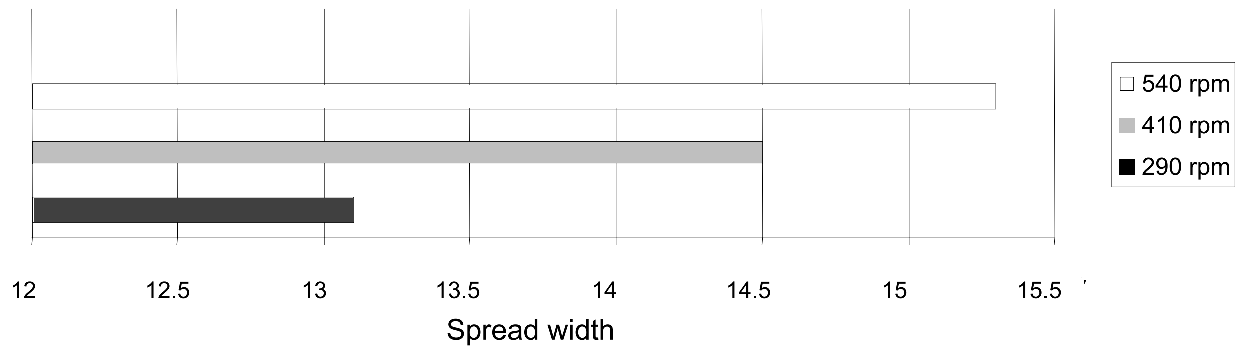

Fig. 2. Rotary spreader spread width at different rpm levels.

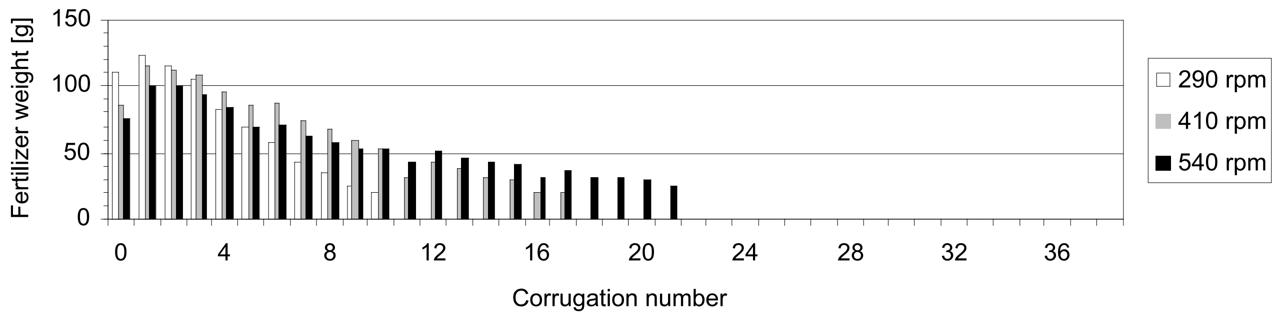

Fig. 3. Pendulum spread pattern width at different rpm levels.

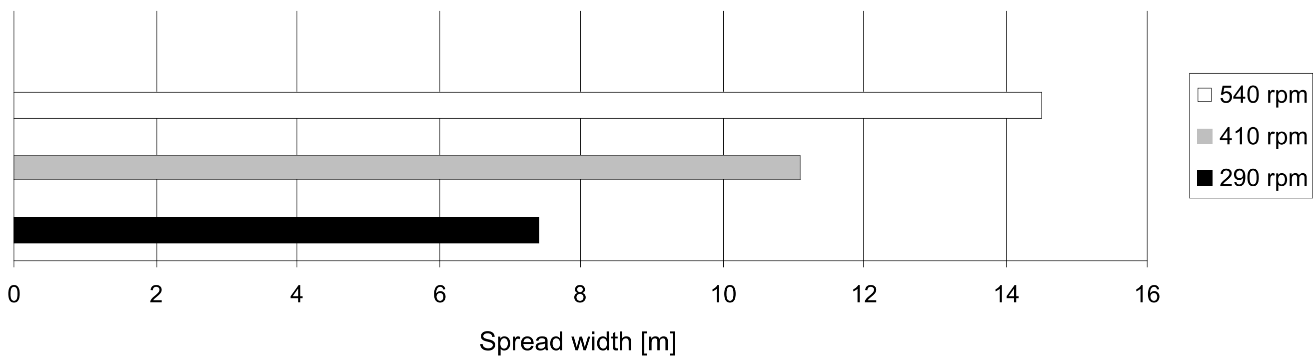

Fig. 4. Pendulum spreader spread width at different rpm levels.

year. And this is also the reason why cultivation of grasses and crops on relatively small areas has been tripled.

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