A SYSTEM FOR SPATIALLY VARIABLE RATE FERTILISER APPLICATION

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PROBLEM

Crop yield may be spatially variable within the same field, because of spatially variable soil characteristics (slope, texture, structure, tilth, pH, etc.), influencing the soil nutrient content (nitrogen, phosphorus, potassium, etc.).
Because of this within-field spatial variability of soil and crop characteristics, in the precision agriculture cycle targeted fertiliser spreading, as well as any spatially variable crop rate input application, may be highly profitable for both environment protection and cost saving.
Unfortunately even if centrifugal and pneumatic fertiliser spreaders equipped with systems able to apply rates proportionally related to machine forward speed and spatially variable are nowadays commercially available, they are very expensive.

OBJECTIVE OF THE PAPER

Therefore the I.T.A.F. Department has designed, developed and set up a system for spatially variable rate crop input application, compatible with most DGPS and agricultural machines (including the fertiliser spreaders), which can apply rates proportionally related to the machine forward speed (Carrara et al., 2001; Comparetti and Orlando, 2001).
This system, which was previously mounted on a herbicide sprayer and successfully tested for spatially variable rate herbicide application (Carrara et al., 2002; Carrara et al., 2004; Comparetti et al., 2001), was mounted on a cheap but reliable centrifugal spreader commercially available.
The paper describes this system in full details and shows the results of the first tests carried out for measuring the reaction time, between the GPS signal receiving and the input transmission by controller (t_0), the setting time, between the input transmission and the shutter position variation (t_1) and the drop time, between the fertiliser release by the dosing system and its falling down on the disc (t_2).
According to previous tests (Griepentrog and Persson, 2001) the mean spreading time (t_3), between the falling down of the fertiliser on the disc and its spreading on the soil surface, being negatively correlated to the particle velocity, depends on the fertiliser type and for the centrifugal spreaders also depends on the characteristics of the discs.
The sum of these times is the adjustment time (t); if this adjustment time is multiplied by the machine average forward speed it is possible to compute the adjustment offset (d_1), which must be compared with the distance from the GPS antenna to the spreading cone centre (d_2).
If d_1 is equal to d_2 the rate is applied in the desired point relying on the application map.
If d_1 is lower than d_2 the rate is applied before the desired point and, therefore, the system must accordingly delay the rate variation; if d_1 is higher than d_2 the rate is applied after the desired point and, therefore, the system must accordingly anticipate the rate variation.

METHODOLOGY

In order to test the system an Amazone ZA-M 900 centrifugal fertiliser spreader was used. This spreader has the following technical specifications: total length of 1.30 m, two single acting control spool valves for opening or closing the two hopper shutter slides (on/off) and two setting levers for the two shutters. By gravity the fertiliser drops on the two spreading discs through the hopper opening.

The spreader was modified as follows: an electrical stepper motor was connected with the hopper shutter slides, using steel wire, and sheaves; a sheave of 60 mm diameter having two grooves, was mounted on the electric motor and two shaves of 120 mm diameter were fitted to the two hopper shutter slides.

The system for spatially variable rate fertiliser application consists of a data sensing system (DGPS mobile receiver, Doppler radar and potentiometer), a data processing system (portable computer, with specifically developed software called Precision Agriculture Controller or PAC); an active control system (Land Manager of DICKEY-john and electric motor), able to apply rates proportionally related to the machine forward speed, varying the two hopper shutter slides. The system is mounted on the tractor carrying the spreader, the electric motor is obviously mounted on the spreader.

The DGPS mobile receiver measures the machine within-field current position and transmits it to the computer. The PAC software reads the rate related to this position in the application map and transmits this rate to the Land Manager; this active control system transmits inputs to the electric motor, regulating the two hopper shutter slides, in order to apply the previously selected rate (Fig. 1).

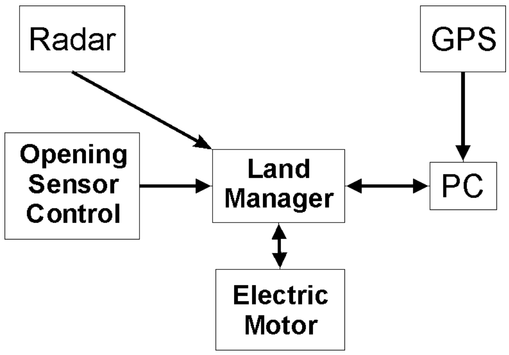

Fig. 1. Scheme of the system for spatially variable rate fertiliser application.

The system was set up relying on the table hopper shutter setting / rate (kg ha^{-1}) provided by the manufacturer for the real working width of 10 m, the average forward speed of 2.77 m s^{-1} and urea 46% N granular fertiliser (particle diameter of 3.30 mm). During the tests the spreader applied fertiliser rates variable from 50 to 400 kg ha^{-1}, in steps of 50 kg ha^{-1}.

It was possible to determine the various time gaps, which constitute the total time interval between the arrival of the GPS signal and the fertiliser spreading on the soil surface.

Both the reaction time (t_0), between the arrival of the GPS signal and the input transmission by the Land Manager to the electric motor, and the setting time (t_1), between the input transmission and the shutter setting variation, were measured.

The drop time (t_2), between the fertiliser release by the dosing system and its falling on the discs, was computed using the formula:

$$t_2 = \sqrt{\frac{2h}{g}}$$

where:

h = height of fertiliser fall;
g = acceleration of gravity.
Then, multiplying the sum of the various times for the machine average forward speed it was possible to compute the adjustment offset (d_1), that is the distance travelled during the adjustment time.
Results from the tests on working quality of fertiliser spreaders show that application rate influence the working quality itself (Weltzien, 2002). Therefore, the system was tested using the following fertiliser rate variations: 0-50 kg ha^{-1}, 50-100 kg ha^{-1} and so on, until 350-400 kg ha^{-1}, in order to graphically represent the setting time depending on the fertiliser rate variation and, the adjustment offset depending on the fertiliser rate variation itself for four machine average forward speeds (of 1.66, 2.22, 2.77 and 3.33 m s^{-1}).

FIRST TEST RESULTS

The result of the tests show that the applied fertiliser rate varies changing the shutter opening angle, according to the following equation:

$$y = 1,8178\, x^2 - 20,121\, x + 83,266$$

This function is represented in Figure 2:

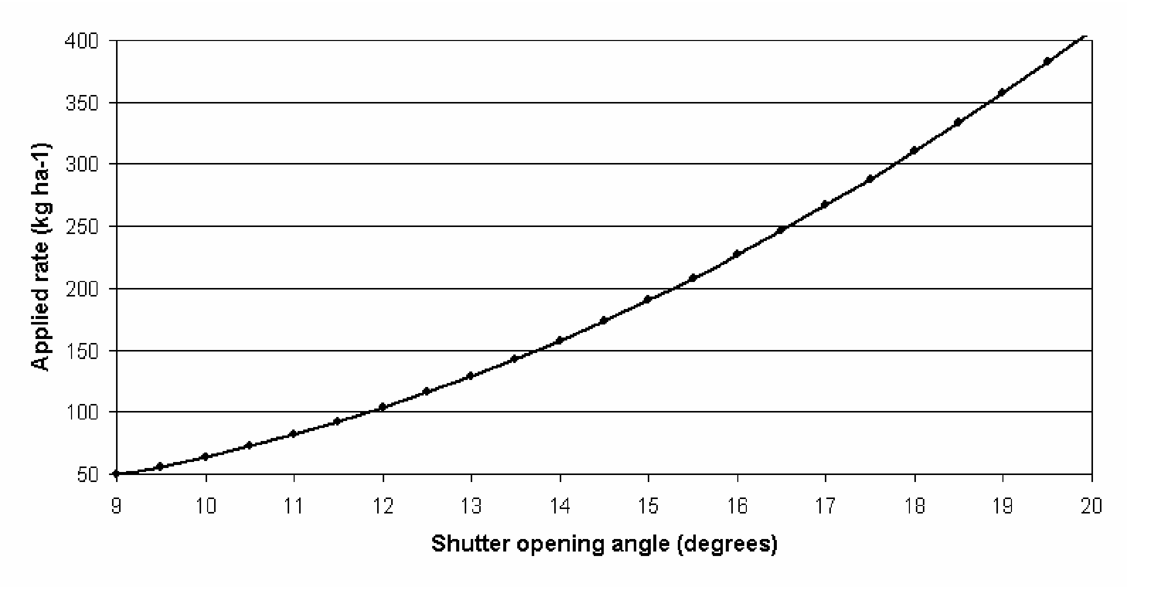

Fig. 2. Curve representing the applied rate versus the angle of shutters opening.

The reaction time (t_0) resulted of one second and does not depend on the fertiliser rate variation.
In the considered fertiliser rate range (0-400 kg ha^{-1}) the setting time (t_1) variation decreases with increasing the fertiliser rate as shown in figure 3.
Also the drop time t_2 = 0,14 s is constant and does not depends on the fertiliser rate variation.
The adjustment offset decreases increasing the fertiliser rate; for each fertiliser rate the adjustment offset increases increasing the machine average forward speed as shown in figure 4.
Moreover from the 100-150 kg ha^{-1} fertiliser rate variation onwards for each rate

variation and for each machine average forward speed the adjustment offset resulted almost constant.

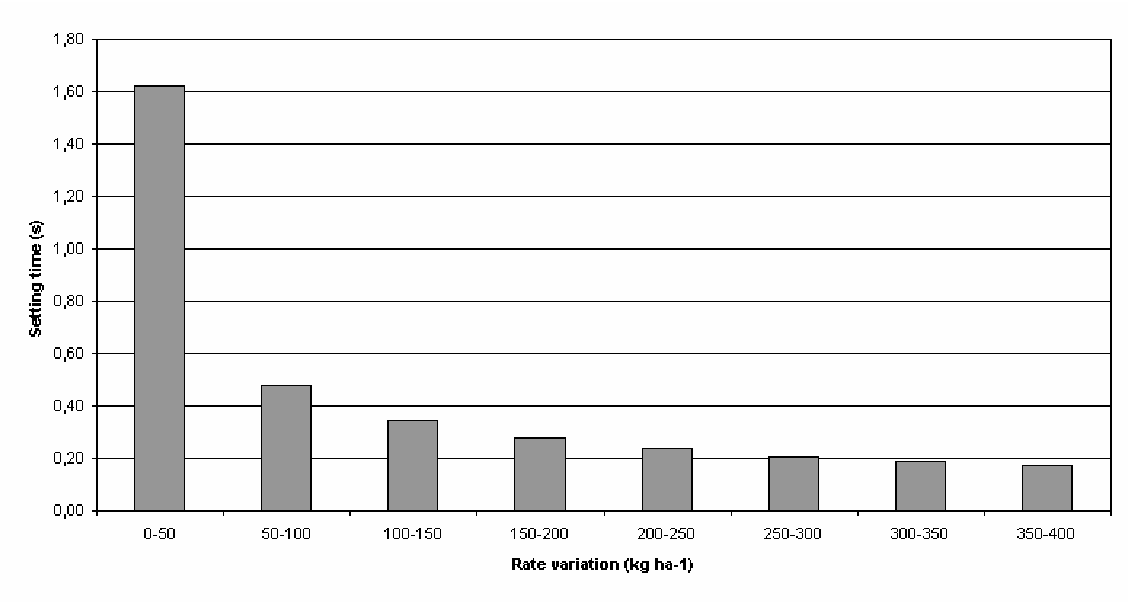

Fig. 3. Setting time versus fertiliser rate variation.

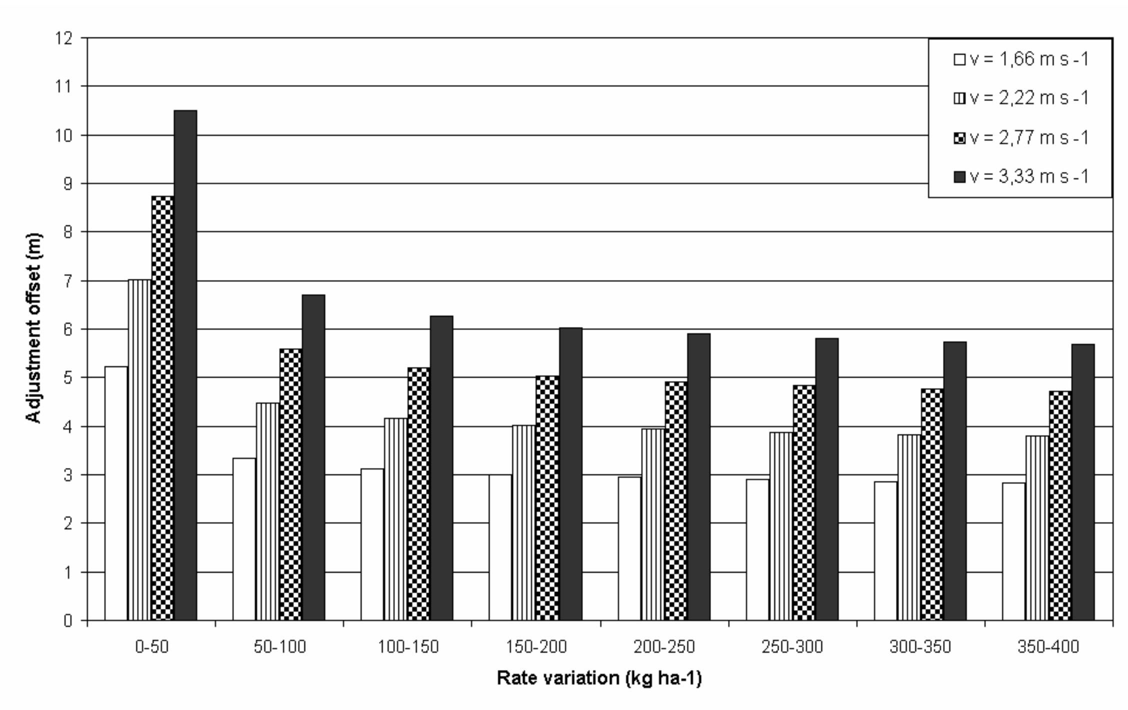

Fig. 4. Adjustment offset versus fertiliser rate variation, for four machine average forward speeds.

CONCLUSIONS

The results show that the adjustment offset of the centrifugal spreader tested is function both of the machine forward speed and of the fertiliser rate set before the input variation.
Being the variation fertiliser rate the same, the adjustment offset increases with the machine forward speed, while it decreases setting higher fertiliser rates.
In order to apply the desired rate according to the application map it is needed to compare the adjustment offset (d_1) with the distance from the GPS antenna to the spreading cone centre (d_2): these two offsets must be equal for performing an optimal spatially variable rate fertiliser application.
If these values are not equal the active system must be able to delay or anticipate the rate variation; this is possible after developing a specific software able to adapt the system to different types of spreaders and different types of fertilisers. Obviously field tests must be carried out to validate the software capability and the system response.
The main components of the system described in this paper can be mounted on different agricultural machines for spatially variable rate crop input application (such as herbicides and fertilisers).
This cheap system can be used also in small and medium farms, having not enough money for buying agricultural machines equipped with different systems for applying different crop inputs.
Moreover this system facilitates the spatially variable rate crop input application, because the effort of the farmer will be concentrated in learning and practicing the use of only one spatially variable rate crop input application system.

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