Tarım Makinaları Bilimi Dergisi (Journal of Agricultural Machinery Science)
2008, 4 (4), 325 - 328

The Precision of Six GPS Guiding Systems in Agriculture

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Abstract: Positioning system by GPS takes a great importance in our daily life. In Agriculture also several applications have been developed and meet an increasing success. For the moment, the current and functioning applications are land surveying, parcel's mapping and simple or auto-guiding.
This study aims to compare the precision of six GPS guiding systems currently marketed. These systems help the driver to maintain the working width between the routes. They should facilitate the marking out of the field and reduce the overlapping. This way, GPS guiding systems should have a positive impact on the rationalisation of the inputs application (fertilizers and pesticides) and on the environment.
The systems were tested in the field in real conditions and under the same circumstances. The two modes of functioning (straight and curved line) have been tested. A protocol has been developed and more than 4500 measurements have been realised.
In the same time, measurements have been led to determine the overlapping during cereals sowing without the help of a guiding system. The objective was to evaluate the added-value of the GPS guiding systems.
In conclusion, most of the studied systems work out correctly and answer, on average, to the precision mentioned by the manufacturers whatever the working conditions. However, the systems vary significantly from each other regarding the variability and the repeatability of their positioning. The study and the analysis of the function mode "curved line " have caused some problems. A specific protocol should be developed in the future.
Key words: Guiding systems, GPS, precision, overlapping

INTRODUCTION

GPS (Global Positioning System) use with the differential correction systems (dGPS) Egnos allows us to reach a precision within 30 cm.

This study aims to determine and compare the precision of six GPS guiding systems in Agriculture : Centerline 220 (LH-AGRO-TEEJET), Cultiva ATC (AUTOFARM), Isaguide (ISAGRI), John Deere GS 2600 (JOHN DEERE), Outback S (AGROCOM) and Sat 3G (GENITRONIC). Only the simple guiding functions of the systems has been studied. For this, the system give information to the driver who manually corrects the trajectory of the tractor.

MATERIALS and METHODS

So as to not disturb the signal, the trials have been realised on an open site without buildings and trees around. Six parallel strips of sand have been installed on the field. They had a length of 80 m and were spaced of 20 m. The strips were perpendicular to the reference line AB.

First the tractor covers the reference line AB (straight or curve) and the guiding system installed on it registers the trajectory. Then several passages parallel to the AB line (straight or curve) have been realised taking into account the information given by the guiding system.

The distance between each route has been measure using the tracks let by the tractor's wheels on the sand trips. Each junction "sand strip x tractor's track » corresponds to one measurement.

At the end, 72 complete trials have been realised : 6 systems, 2 modes of functioning (straight and curve), 2 widths and 3 repetitions. In total, 2376 spaces between passages have been measured for the 6 systems.

The antennas of the guiding systems were placed on the tractor's bonnet above the front axle. The forward speed was between 6 and 7 km/h for the whole trial. Egnos was the dGPS correction system used for the whole test.

RESEARCH RESULTS

Overlapping during cereals sowing

First, in order to evaluate the added value of a guiding system, measurements have been done in fields of wheat and barley. These fields have been sowed without GPS guiding system. One showed an overlapping ranging from **2 to 8 %**. This overlapping will have certainly an impact on the next works as fertilization and pesticides applications.

Straight line

Spaces between routes have undergone a statistical analysis and the descriptive parameters have been calculated (Table 1). The frequency distribution of the spaces between the routes of the tractor has been also calculated.

One observes that all systems generate, on average, spaces between routes higher than the expected working width (8 or 20 m), excepted for Genitronic. This one generates an overlapping, while the others produce gap.

For **8 meters** working width, all systems answer, on average, to the precision of ± 20 cm. Cultiva and Isaguide present the best performances with a deviation of only 1 cm. With an average deviation of 15 cm, Genitronic will produce an average overlapping of ± 2%.

The systems make the difference for the standard deviation. Cultiva presents a lower variability (s = 12 cm) than Isaguide (s = 28 cm). Although those both systems have the same average precision, the widths generated by Cultiva will be generally closer to the expected working width. Genitronic generates a very high variability (s = 124 cm).

For **20 meters** working width, John Deere, Isaguide and Cultiva present a good average precision. Genitronic confirms its imprecision which corresponds always to an overlapping of ± 2 %.

The frequency distribution is an other tool which allows us to characterise the good functioning of the systems. Ideally, the frequency distribution should present the shape of a Gaussian curve : highest frequency for the average width which should be equal to the expected working width. Figures 1 et 2 show two extreme frequency distribution : Genetronic and John Deere for the 8 m working width.

The Genitronic produces widths generally deviating from the expected and they are highly variable. On the contrary, John Deere generates consistent widths whom the frequency distribution is of Gaussian type centred around the expected working width (8 m).

Curved line

This mode of functioning seems identical to the straight one : the GPS guiding system bases the building of the tractor's routes on the reference line (AB) and the ordered working width, while minimising the overlapping

Table 1. Performances ($\bar{x}$, s, Min. and Max. in m) of the 6 GPS guiding systems, straight line, for 8 and 20 m working widths

Systems	Working width : 8 m				Working width : 20 m			
	Average ($\bar{x}$)	Standard deviation (s)	Min.	Max.	Average ($\bar{x}$)	Standard deviation (s)	Min.	Max.
Centerline	7.98	0.19	7.40	8.61	20.12	0.40	19.18	21.00
Cultiva	8.01	0.12	7.72	8.47	20.03	0.22	19.25	20.82
Isaguide	7.99	0.28	6.49	9.65	20.01	0.28	18.93	21.52
John Deere	8.02	0.16	7.67	8.49	20.00	0.13	19.64	20.25
Outback	8.07	0.35	6.75	9.40	20.18	0.20	19.70	20.65
Genitronic	7.85	1.24	4.96	12.00	19.55	1.11	13.86	22.53

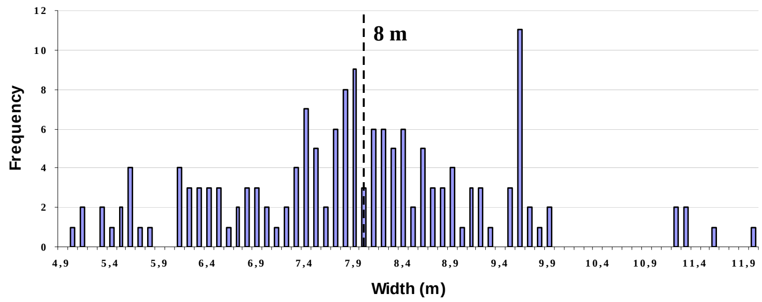

Figure 1. Frequency distribution of the widths generated by Genitronic

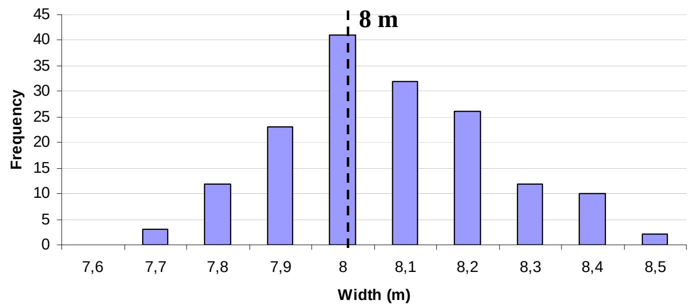

Figure 2. Frequency distribution of the widths generated by John Deere

To do that, two assumptions could be made :

- The GPS system builds the next route by simple linear translation of the previous curved line (Figure 3),
- The GPS system builds the next route by orthogonal translation of each point of the previous curved line (Figure 4).

Following the first hypothesis, the building of the curved routes by simple linear translation is done perpendicular to the reference straight line AB on a distance equal to the working width (Figure 3). This mode of functioning causes problem in terms of overlapping. Generally the machine (sprayer, fertilizer spreaders…) works perpendicular to the tractor's trajectory. The more the working axle will deviate from the translation axle, the more the overlapping will be important.

On the other hand, if one retains as working hypothesis that the mode of routes building is realised by orthogonal translation, one notices that the trajectory will be bent a bit more for each new routes. As illustrated on Figure 4, the curved trajectory could be considered as a circle whom the radius will increase of the working width value for each new route.

This mode of functioning cause a bending of the initial curved line. At the end (tending towards infinity), the last route could be theoretically not more curved, but perfectly straight.

As shown by these considerations, the treatment of the data from the trials done for the curved line was not evident. However, a part of the observed values has been exploited and Table 2 gives some descriptive parameters.

The results for curved lines confirm the one obtained for straight lines. Again, one observes that all systems generate, on average, spaces between routes higher than the expected working width (8 or 16 m), excepted for Genitronic.

CONCLUSIONS

This study allowed us to make the point on the precision and the usefulness of the GPS guiding systems.

- The announced precision is often on the rendezvous and for some systems is yet better (overlapping or gap < 2 %). But we don't have to forget that the results, sometimes very good, are averages and that the deviations could be occasionally important.
- Without using GPS guiding systems, the overlapping could reach from 2 to 8 %, right from the sowing of the crops (wheat and barley).

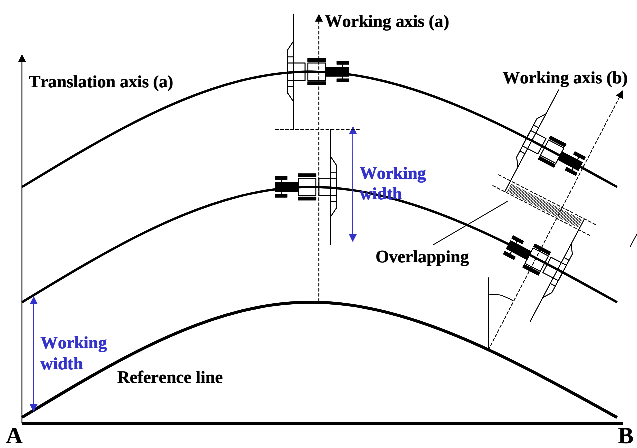

Figure 3. Building of the curved routes by simple linear translation

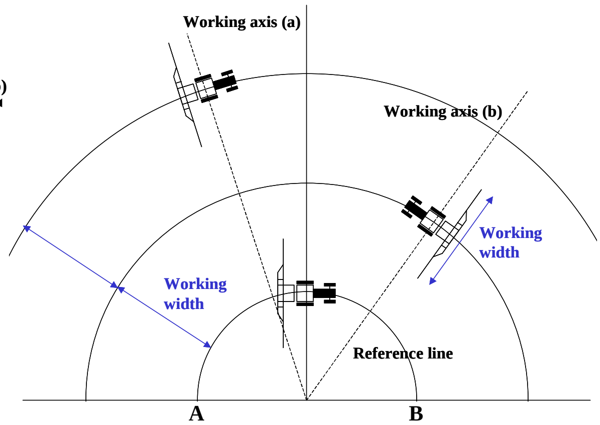

Figure 4. Building of the curved routes by simple orthogonal translation of each point

Table 2. Performances ($\bar{x}$, *s*, Min. and Max. in m) of the 6 GPS guiding systems, curved line for 8 and 16 m working widths

Systems	Working width : 8 m				Working width : 16 m			
	Average ($\bar{x}$)	Standard deviation (*s*)	Min.	Max.	Average ($\bar{x}$)	Standard deviation (*s*)	Min.	Max.
Centerline	8.00	0.49	6.10	9.31	16.49	0.41	15.86	17.35
Cultiva	8.02	0.12	7.76	8.23	16.10	0.11	15.80	16.27
Isaguide	8.08	0.16	7.77	8.37	16.16	0.17	15.92	16.72
John Deere	8.03	0.14	7.71	8.32	16.01	0.25	15.62	16.57
Outback	8.11	0.19	7.67	8.70	16.24	0.19	15.95	16.70
Genitronic	7.88	0.88	5.96	10.24	15.84	0.76	14.38	18.57

- The results allow us to consider the GPS guiding systems really useful and adapted for the agrochemicals application (fertilizer and pesticides), or to the use of large machines.
- A specific protocol should be developed for the study of the curved line mode of functioning.

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