

Sowing efficiency of two seeding machines with different metering devices and distribution systems: a comparison using soybean, *Glycine max* (L) Merr.

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Abstract

Argentina has experienced changes in its agricultural production, moving from traditional practices which greatly disturbed soils towards systems that reduce soilworking. Direct seeding is a good example of the latter. Seeding machines have improved significantly in recent years, incorporating new technical and functional features. Two seeding systems are used in soybean cultivation: the traditional method which relies on planters equipped and drills (which plant in rows). The second option allows the use of a single seeding machine for wheat-soybean rotation and is the object of growing market interest. The aim of this study was to compare two direct seeding machines representative of these systems. The following variables were recorded: a) the «treatment» received by the seed (as determined by seed viability), b) the relationship between plants grown and seeds planted per row, c) the uniformity of plant distribution per linear meter of furrow, and d) yield per linear meter of furrow plus yield as kg ha⁻¹ at harvest. The trial was performed in 12 randomly selected plots at Nogoyá (Entre Ríos, Argentina), which for the last six years had been direct-seeded. The results obtained were compared using the Tukey test (significance set at $p < 0.05$). Significant differences were found in favour of the planter with respect to «treatment» received by the seed, the quantity of viable seed distributed, sowing efficiency and yield per linear meter of furrow.

Key words: drills, planters, sowing efficiency, yield, seed viability.

Resumen

Siembra directa de soja, *Glycine max* (L) Merr.: eficiencia de implantación de dos sembradoras con diferentes sistemas de dosificación y distribución

Argentina experimentó cambios productivos, transitando de la agricultura tradicional con alto grado de disturbación del suelo hacia sistemas tendientes a reducirlo, siendo la siembra directa un exponente de ello. En este contexto, las máquinas sembradoras experimentaron una gran evolución, cambiaron sus características técnicas y se modificaron sus funciones. En el cultivo de soja se observan dos modalidades de implantación: la tradicional mediante sembradoras para cultivos de escarda y la alternativa constituida por sembradoras para cultivos en masa, en hileras. Esta segunda modalidad posibilita utilizar una sola máquina en la rotación trigo-soja de segunda y muestra un interés creciente en el mercado. El presente trabajo compara dos máquinas para siembra directa representativas de ambas alternativas. Se realizaron las siguientes determinaciones: a) tratamiento otorgado a la semilla analizando su viabilidad, b) la relación entre plantas logradas respecto a semillas distribuidas en la hilera, c) uniformidad de distribución de plantas por metro lineal de surco, d) rendimiento por metro lineal de surco y en kg ha⁻¹ a la cosecha. El ensayo se realizó en un lote de producción con seis años de antecesores en siembra directa, del Departamento de Nogoyá (Entre Ríos), sobre doce parcelas sorteadas al azar. Los datos se contrastaron mediante el test de Tukey ($p < 0,05$). Los resultados favorecieron a la sembradora de escarda en el tratamiento a la semilla, la cantidad viable distribuida, la eficiencia de implantación y el rendimiento por metro lineal de surco.

Palabras clave: sembradoras para cultivos en masa en hileras, sembradoras de escarda, eficiencia de implantación, rendimiento, viabilidad de semilla.

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Introduction

In Argentina, two sowing methods are used for soybean crops: the traditional method, which uses planters, and seed drills for cultivation in rows (Bragachini *et al.*, 1993). The latter allows the same seeding machine to be used in wheat-soybean rotation regimens.

When a crop is planted, the aim is to establish a plant population whose spacing contributes to the maximum return per surface area (Kepner *et al.*, 1982). Optimising the density of plants is a prime importance, and this requires precision in terms of seed metering and distribution by the seeding machine. The objective of seed metering is accurate and uniform seeding (Jorgenson, 1988) that causes no damage to the seed (Baraño, 1955).

Seed distribution refers to the planting of seeds according to a predetermined pattern (Colombino *et al.*, 1989). This should take into account the requirement for equidistant spacing between seeds. The depth at which they are planted should be adjusted to provide them the best moisture conditions (Kumar, 1989). It is therefore important to take into account the components of the drill and the possibilities of their adjustment.

Several authors have tried to determine the optimum spacing between rows in soybean cultivation (working with different varieties), and obtained higher yields when distances between furrows were smaller than the traditional 70 cm row width (Meira *et al.*, 1980; Bodrero *et al.*, 1989; Schapovaloff and Bogado, 1989; Tejerina and Herbas, 1989). This favours both seeding with drills for cultivation in rows and the use of planters.

Planters sow seeds individually in furrows according to a predetermined pattern, while drills meter plant seeds in a steady flow. With respect to soybean, individual seed metering is possible for up to 30 seeds per linear meter of furrow. For higher densities, however, a flow of seeds is required (Maroni and Medera, 1990). Soza *et al.* (1996) compared individual and flow metering systems and found a coefficient of variation for seed spacing uniformity within rows of 74.33-76.19% for the first and 94.86-97.77% for the second-values regarded as high according to the classification of Pimentel Gomes (1978). Nave and Paulsen (1979), who analysed five seed metering devices involving either individual metering or flow systems, obtained values in seed spacing uniformity of between 84% and

97%, with no significant differences between specific treatments. In other tests, Fábregas *et al.* (1995) studied the damage inflicted on soybean seeds by internal double-run metering and concluded that they were treated satisfactorily. Earlier, Ewen *et al.* (1981) indicated the indifference of this crop with respect to uniform seed distribution and reported that seeding machines with either individual metering devices or flow systems could be used. However, Cavalheiro Touriño and Daniel (1996) indicated that an irregular distribution leads to increased losses at harvest and the sub-optimum use of soil resources. The most efficient planting system is therefore a matter of some debate.

The increasing world demand for food needs to be met, but technologies should be employed that guarantee the sustainability of agricultural systems. Direct seeding is an alternative that should be considered since it helps establish a better soil structure, increases soil organic matter content, and improves rainwater infiltration and retention capacities (Méndez Duhau and Satorre, 1998; Gil, 1999). However, it has the drawback that the drill has to operate on plots with abundant surface stubble, with all the difficulties this entails-such as the attention required by the distribution train and the particular care necessary in the use of the furrower if planting is to be efficient (Brown and Baker, 1986).

Many distribution trains for direct seeding have a rolling coulter and a double disc furrower that can be used on many types of soil (Tice and Hendrick, 1991; Morrison *et al.*, 1996). Richey (1981) indicates that they produce a V shaped furrow with smooth sides, reduce the dispersion of seeds, and contribute to the flow of moisture towards them. In his review, Baker (1994) describes that this assembly can operate without choking, although furrow walls can be left compacted, little loose soil is produced with which to cover the seeds, stubble can be introduced into the furrow, and seeds can be inadequately placed. These problems impair germination and emergence. Maroni (1994) report that furrow wall compaction is worse when the furrowers are required to break the soil without prior preparation with a coulter.

An alternative distribution train for drills is the double disc opener, composed of a double disc furrower equipped with a displaced assemblage or discs of different diameter, the idea being that the forward disc mimic the action of a rolling coulter. This helps to reduce the number of machine parts and increases penetration (Baumer *et al.*, 1994). The drawback is premature

wearing of the forward disc and the rubbing of components. The lateral walls of the furrows produced may also be excessively compacted (Maroni, 1994).

The above distribution trains thus have a common disadvantage: the compaction of the lateral wall of the sowing furrow. If soil is tightly packed around the seed, its chances of obtaining sufficient air for germination are reduced. Even if it does manage to germinate its roots may not be able to explore for water and nutrients with sufficient speed (Bragachini *et al.*, 2001). The number of plants obtained is therefore less than the number of viable seeds sown.

Direct seeding requires special attention be paid to seed drills in terms of their assembly and regulation; care needs to be taken in the analysis of the alternatives for covering the seed.

The aim of the present work was to compare the seed uniformity and distribution results achieved with two direct seeding machines (a planter and a drill for planting in rows) equipped with different seed metering devices and distribution trains.

Material and Methods

The trial was performed in 2002-2003 on land in the Departament of Nogoyá, 32° 24' S, 59° 48' W, in the Province of Entre Ríos, Argentina, where direct seeding had been practised for the previous six years.

The soil of the area is an Aquic Argiudol, with a fine, mixed, slightly alkaline thermal texture, corresponding to the Aragón series. Typical profiles were composed of an A1 horizon of 9 cm thickness and 4.1% organic matter. The argilic horizon, which was of prismatic

structure, varied in thickness from 34-45 cm and had a clay-silt texture. Horizon C, a clay-silt loam, lay at depths below 45 cm. All horizon profiles were dotted with ferromagnesian elements, although these were only abundant from B31ca. The soil was slightly alkaline from B21t onwards, with as high as 8% sodium exchange (Instituto Nacional de Tecnología Agropecuaria, 1993).

Mean precipitation in the area is 970 mm, although interannual variability is great. Maximum rainfall (50% probability) occurs from the end of October to mid May. Frosts occur from the 29th August to 30th May.

The crop grown on the experimental land prior to the experiment was maize. After harvest, 3 l ha⁻¹ of 48% glyphosate was applied, along with 0.5 l ha⁻¹ of 40% 2-4D and 1 l ha⁻¹ of 10% imazethapyr, which left a stubble coverage of 60%.

Twelve plots were marked out perpendicular to the line of sowing. Six were randomly selected for each of the two methods to be compared. All these plots were 1 m long, and had a width corresponding to eight furrows.

The two seeding machines compared were an Apache SMA 6100 (TA) and a Semeato TD 400 (TS). Table 1 shows their characteristics.

The seed used was soybean cv. Don Mario 501, group V maturity.

The seeding machines were adjusted while stationary to provide a density of 20 seeds m⁻¹ of furrow plus 60 kg ha⁻¹ of calcium triple superphosphate, verified in the field at a speed of 6 km h⁻¹. Samples of the metered seeds were taken to assess their germination capacity and to check for visible damage (ISTA, 1993). The control seeds were analysed in the same way. The

Table 1. Characteristics of the seeding machines used in the study

Characteristics	Apache SMA 6100 (TA)	Semeato TD 400 (TS)
Type of seeding machine	Planter	Drill
Number of units	9	24
Distance between row spacing	520 mm	158 mm ¹
Seed metering system	Individual	Flow
Type	Skew seed plate planter	Fluted roller meter
Cutting and soil penetration	Smooth coulter blade (16")	Without coulters
Furrower	Double disc with double depth limiting wheel	Staggered double disc opener ²
Coverer and/or compacter	Covering-compacting wheels (variable angle)	Tooth harrow units

¹ Eight were used resulting in 474 mm between rows. ² In this machine, the double disc opener acts as a coulter-opener.

«treatment» received by the seed from the different metering systems was determined from the number of viable seeds planted. Before sowing, the number of seeds per linear meter of furrow and the uniformity of longitudinal distribution were determined. For this, the seeding machines were assembled with their packers removed. For each treatment, 10 × 1 m long furrow fractions were randomly chosen and the number of seeds discharged recorded, as well as the distance between them.

The number of plants per linear meter was determined in each plot at 15, 22 and 29 days after sowing. The sowing efficiency (e_i) of the treatments was determined by the relationship between the number of plantlets obtained and the number of viable seeds sown [1]. This was determined from the number per meter of furrow adjusted by a viability coefficient, C_{vb} (Soza *et al.*, 1998). This coefficient is the product of germination capacity and the visible damage of the metered seeds at the sowing speed [2].

$$e_i = \frac{\text{Plant obtained}}{\text{seeds sown} \times C_{vb}} \quad [1]$$

$$C_{vb} = \frac{GC (\%)}{100} \times \frac{100 - VB (\%)}{100} \quad [2]$$

where e_i : sowing efficiency, C_{vb} : viability coefficient, GC: germination capacity, and VB: visible damage.

On the last date, the longitudinal uniformity of the plants in the furrow was also determined. The plots were eventually harvested manually and weighed to determine the yield per linear meter of furrow. Yield ha^{-1} was also calculated.

Tukey's test was used to determine whether there was any difference in the treatment received with respect to the seed metering devices, and to compare the uniformity of distribution of seeds per linear meter of furrow, the yield per linear meter of furrow, and the yield per ha^{-1} . Significance was set at $p < 0.05$.

Results

Treatment received by the seed by the different planting systems

The TA method treated the seeds more kindly: germination capacity fell by only 0.25%, and visible damage increased by only 0.29% compared to controls, while the TS treatment reduced germination capacity by 4% and increased visible damage by 0.79%. Only the viability coefficient for the TS treatment fell compared to controls (Table 2).

Uniformity of distribution in the sowing line

Table 3 shows the results of the variables analysed. Through the adjustment of the two metering systems, quantitative behaviours were achieved that were not significantly different. However, the TA method had a higher number of viable seeds per meter of furrow, obtained through the effect of its coefficient of variability. The greater uniformity of discharge obtained by means of the coefficient of variation is notable. The TA method also led to less variation in the distance between seeds (31.34% compared to 59.53% for the TS system).

Sowing density achieved with each system

The seeding machines tested have different distances between their seed furrowers; the TS system is shorter and therefore makes more furrows per hectare. Further, when so regulated, it can deliver more seeds. After adjustment for the number of viable seeds per linear meter of furrow, the seed density obtained with the TS system was significantly better. However, the

Table 2. Treatment received by seeds in the two methods

System	Germination capacity			Visible damage			Cvb
	Mean (%)	SD (%)	CV (%)	Mean (%)	SD (%)	CV (%)	
Control	97.25 a	1.50	1.54	0.33 a	0.13	41.13	0.96
TA	97.00 a	1.15	1.19	0.62 b	0.25	40.00	0.96
TS	93.25 b	1.70	1.83	1.12 c	0.25	22.22	0.92

Different letters in the same column indicate significant differences (Tukey's test, $p < 0.05$). SD: standard deviation. CV: coefficient of variation.

Table 3. Number of seeds discharged per linear meter of furrow, number of viable seeds per linear meter of furrow, and distance between seeds

System	Number of seeds discharged per linear meter of furrow		Number of viable seeds per linear meter of furrow		Distance between seeds (cm)	
	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)
TA	19.62 a	5.40	18.84 a	5.40	5.065	31.34
TS	19.50 a	9.88	17.94 b	9.88	5.279	59.53

Different letters in the same column indicate significant differences (Tukey's test, $p < 0.05$). CV: coefficient of variation.

Table 4. Sowing density achieved by the two methods

System	Viable seeds (ha^{-1})			Viable seeds (kg ha^{-1})	Total (kg ha^{-1})
	Mean	SD	CV (%)	Mean	Mean
TA	362,292.88 a	16,912	4.66	60.65	63.18
TS	383,332.25 b	34,015	8.87	64.58	70.20

Different letters in the same column indicate significant differences (Tukey's test, $p < 0.05$). SD: standard deviation. CV: coefficient of variation.

TS system with flow metering showed a greater variability of distribution (Table 4). If the 1000 grain weight is taken into account, these densities can be expressed in kg ha^{-1} : the TS method sowed 3.93 kg more seed per hectare than the TA method, which rises to 7.02 kg when germination capacity and visible damage are taken into account.

Sowing efficiency

With respect to planting efficiency, Table 5 shows differences in favour of the TA system. This suggests better a functioning of its distribution train in the achievement of a good seed-soil relationship, and a greater uniformity of emergence compared to the TS system (Bragachini *et al.*, 1993). These results are supported

Table 5. Sowing efficiency

System	Mean	SD	CV (%)
TA	0.88 a	0.12	13.76
TS	0.65 b	0.18	27.75

Different letters in the same column indicate significant differences (Tukey's test, $p < 0.05$). SD: standard deviation. CV: coefficient of variation.

by those obtained in successive recounts; Table 6 shows there were no significant differences for the three sampling dates.

The distances between the plants obtained are in agreement with the above results. With TA, a close relationship was seen between distance between seeds and distance between plants (5.065 cm and 5.96 cm respectively), while a much less clear relationship was seen with TS (5.279 cm between seeds and 8.49 cm between plants). The variability seen with the TS system was also greater (Table 7).

Yield

The yield obtained per linear meter of furrow (Table 8) was better with the TA system. This com-

Table 6. Number of plants obtained per linear meter of furrow

Days after sowing	TA	TS
15	16.18 a	11.66 a
22	16.48 a	11.70 a
29	16.55 a	11.75 a

Same letters in the same column indicate no significant differences (Tukey's test).

Table 7. Distance between sown and plants obtained at the third sampling date

System	Distance between seeds		Distance between plants	
	Mean (cm)	CV (%)	Mean (cm)	CV (%)
TA	5.065	31.34	5.96	73.6
TS	5.279	59.53	8.49	95.7

CV: coefficient of variation.

pletes the trend seen from treatment received by the seed during metering, through to the better distancing between the plants obtained. The yield in kg ha⁻¹ obtained with the two systems was not significantly different, but it should be noted that the TS system involved a larger number of furrows and a greater quantity of seed sown per hectare.

Discussion

The seed received better treatment in the TA system, i.e., the deposited seed had a better germination capacity and showed less visible damage (Table 2). These results were expected given the lack of a cut-off in the seed plate planter metering device in the TA system, plus the fact that soybean is a soft tegument seed. The germination capacity of seed metered by the TS system fell 4.11% compared to the control seed plate planter, while the TA system caused only a 0.25% reduction. In addition, the visible damage caused by the TS system was close to the tolerance limit of 1% (Klenin *et al.*, 1986).

Owing to its metering device, the uniformity of distribution was worse with the TS system (Table 3). This needs to be taken into account when species are sown that require precision in terms of the number of seeds

Table 8. Yields obtained

System	Yield per meter of furrow		Yiel per hectare	
	Mean (g)	CV (%)	Mean (kg)	CV (%)
TA	155.50 a	14.22	2,967.20 a	14.22
TS	142.00 b	11.48	2,868.80 a	11.48

Different letters in the same column indicate significant differences (Tukey's test, $p < 0.05$). CV: coefficient of variation.

deposited per linear meter. The significant difference between the two systems with respect to the number of viable seeds sown per meter of furrow is a product of the coefficient of viability. Although the variability seen with the two present systems was lower than that reported by Soza *et al.* (1996) and Nave and Paulsen (1979), the coefficient of variability of the distance between seeds for TS was almost double that of the TA system.

Brown and Baker (1986) placed great importance on the action of the furrower in the obtaining of high emergence rates. The greater planting efficiency of the TA system (Table 5) suggests that having the coulter in front of the double disc furrow improves its performance. This result contrasts with that indicated by Baker (1994) for such a distribution train, who report poorer germination and emergence. The sowing efficiency obtained with the TS system agrees with that reported by Maroni (1994) in that the double disc opener did not generate soil conditions as favourable as the triple disc. The results of Table 6 support this: the number of plants obtained at the three sampling dates were not significantly different (crop emergence was therefore complete 15 days after sowing and there was no tendency for the plants to die).

Table 7 shows the overall effect of the two metering and distribution systems: the greater uniformity achieved with the individual metering device of the TA system has a positive effect on final yield per meter of furrow, although this is not borne out in terms of kg ha⁻¹ (Table 8). Overall, planters would seem to be the better choice for soybean crops.

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